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Hydraulic Modelling Report

Grimescar Dike – Burn Road, Huddersfield

Wiggett Construction Group Ltd

SHF.1935.001.HY.R.002.A

'Experience and expertise working in union'

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Grimescar Dike, Burn Road

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Executive Summary

This report presents the process undertaken and the findings of a 1D2D ESTRY TUFLOW Hydraulic Modelling study for Grimescar Dike at Burn Road, based on 1m DTM LIDAR Data, detailed channel and structure survey. The model objective is to refine and establish associated baseline flood extents for the proposed development Site.

The model was run for a range of return periods to establish the baseline fluvial flood extents and parameters, including blockage assessments for key in-channel structures. A sensitivity analysis was carried out to understand the seasonal effects of vegetation and impact of downstream boundary levels upon model results within the Site.

The results from the modelling exercise show a variation in flood extent in the Site when compared to Environment Agency Flood Zones. The Environment Agency flood map shows the Site as being entirely in Flood Zone 1; however, surface water flood mapping indicates surface water flooding associated with the channel.

The increase in flood outlines is as expected as Grimescar Dike are not included within the available Environment Agency mapping and is supported by the results of sensitivity model runs.

Scrutiny of Environment Agency surface water Mapping with OS mapping and LIDAR shows that the surface water outlines reflect the topography of the existing channel, which is contained within steep banks on either side. The surface water mapping appears to account for Halifax Road and Burn Road culverts at the west and east of the Site respectively, and also the culverted section within the eastern part of the Site.

A comparison of Environment Agency 1 in 100-year surface water mapping (medium risk) and modelled 1 in 100-year flood extent for Grimescar Dike shows that flood extents are largely reduced across the Site and the model extent. This is likely due to the Grimescar Dike channel being underrepresented in the coarse grid used in the surface water mapping.

A comparison of Environment Agency 1 in 1000-year surface water mapping (low risk) and modelled 1 in 1000-year flood extent for Grimescar Dike shows that flood extents are reduced across the Site and model extent.

The variation between the modelled flood extents for Grimescar Dike and the surface water mapping is likely due to the inclusion of detail such as channel cross sections, structure conveyance and also landforms representative of the present day.

Sensitivity analysis shows that overland flow pathways are not sensitive to downstream boundary changes and have low sensitivity to manning's roughness changes.

The hydraulic modelling exercise has demonstrated the existing/baseline fluvial flood outlines as a result of inclusion of in-channel structures, representative of the Grimescar Dike channel and high-resolution ground model.

1.0 Introduction

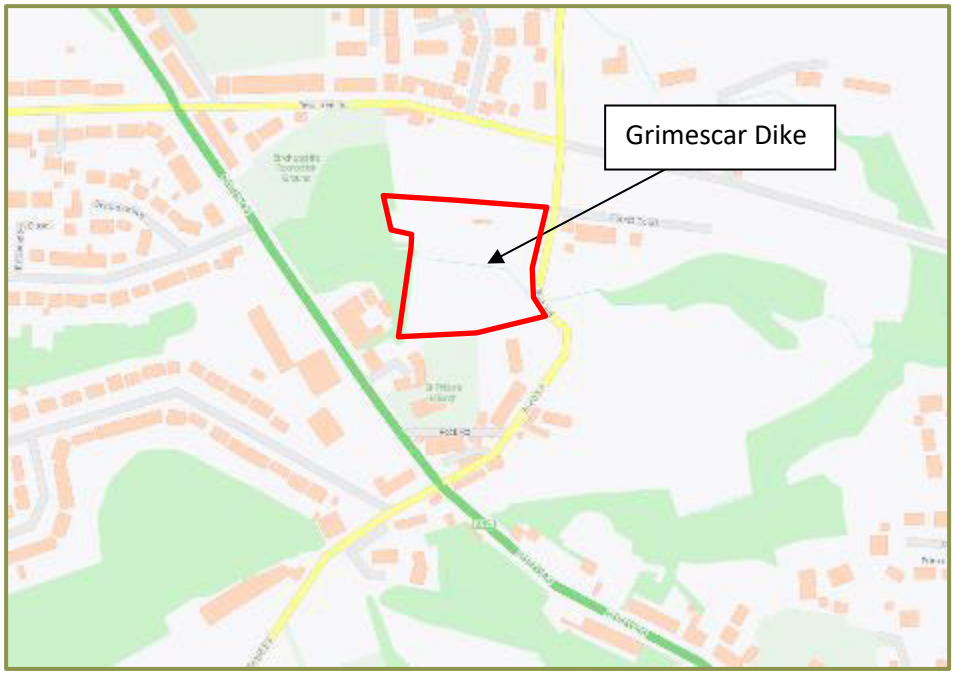
1.1 Background

1.1.1 Enzygo Ltd were commissioned by Wiggett Construction Group Ltd to undertake a hydraulic modelling exercise to determine, and refine, fluvial flood extents associated with Grimescar Dike. The area in question is centred at (NGR) 411973, 418919 and is proposed to be a residential development.

1.1.2 In order to aid the design of the proposed development, and assess modelled parameters against national flood risk guidance, a hydraulic modelling assessment was undertaken. This hydraulic modelling report has been prepared as a stand-alone report (SHF.1935.001.HY.R.001.A, November 2021).

1.1.3 An initial desk top study identified that Grimescar Dike (an 'ordinary watercourse'), conveys flow north-west to south-east through the centre of the Site. Grimescar Dike appears to originate approximately 2km to the north-west of the Site before conveying south-east in a deep, incised channel. It is then culverted under Hailfax Road, which forms the north-west Site boundary. Grimescar Dike then conveys flow south-east through the Site before entering a culvert under Burn Road. The location of Grimescar Dike, in relation to the development Site, is provided in Figure 1.1 and 1.2.

Figure 1.1: Environment Agency Main River Map



1.1.4 In 2018, a Flood Risk Assessment (FRA) was produced by a 3rd party consultant to support a residential development within the Site. Environment Agency flood map for planning shows the Site is located in Flood Zone 1 (Figure 1.2). However, the Flood Zone 1 designation is due to no high level or detailed modelling having been undertaken due to the small catchment size. As such, the flood map for planning is not representative of fluvial flood risk to the Site.

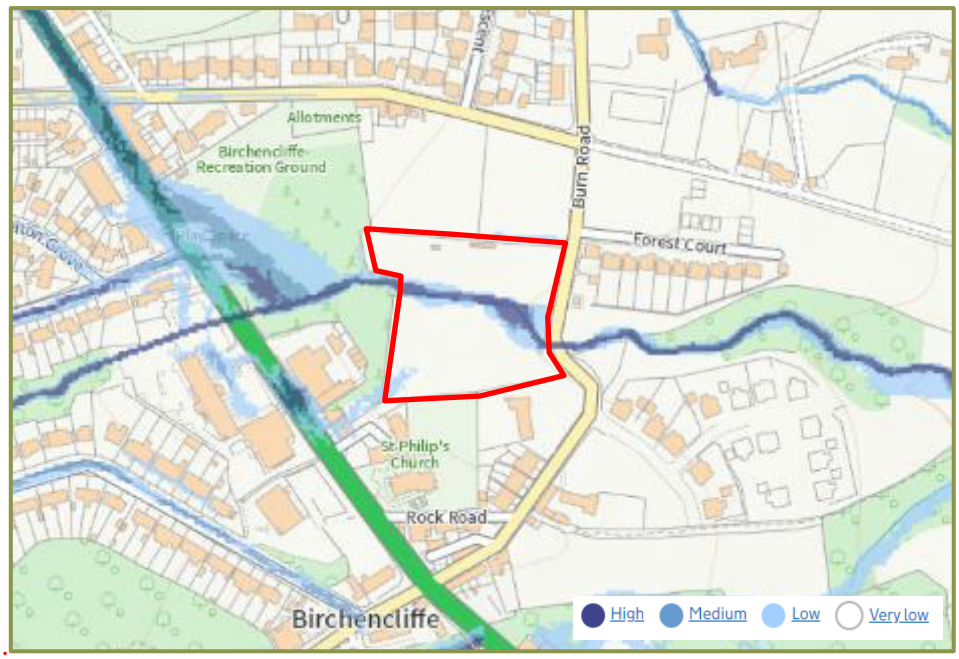
1.1.5 However, it should be noted that the Environment Agency long term flood risk surface water mapping shows that either side of Grimescar Dike has a low to high risk of surface water

flooding (Figure 1.3). The surface water flood extent is likely to be representative of fluvial, rather than surface water flooding as it follows the path of Grimescar Dike. Surface water mapping is high level and does not include details such as, channel or structure survey and also utilises a coarse ground model.

Figure 1.2: Environment Agency Flood Map for Planning Map



Figure 1.3: Environment Agency Long Term Surface Water Mapping



1.1.6 Following submission of the FRA, the Lead Local Flood Authority (LLFA) have requested the following works to enable a full understanding of flood risk from Grimescar Dike within the Site.

- A watercourse study of potential flows in storm periods is required to understand the extent of the flow channel and depth of water in various scenarios to fully understand constraints on development.
- An understanding on culvert size, capacity and condition on site is required as part of the above assessment. This clearly applies to Burn Road culvert but any model will need to be re-run for alterations for culverts under the access road.
- An assessment needs to consider accommodation of trash/safety screen erection to protect blockage under both the estate road and Burn Road.

1.1.7 As such, a detailed hydraulic modelling assessment was undertaken, inclusive of detailed channel and structure survey, topographical survey and site walkover observations to refine the fluvial flood extents.

1.2 Purpose

1.2.1 The purpose of this Hydraulic Modelling report is to confirm the flood outlines associated with Grimescar Dike in order to inform the proposed layout for the development Site and associated surface water drainage strategy. This report will:

- Present the methodology to build/run the baseline hydraulic model.
- Report the results in tabular and mapping format.

1.3 Scope

1.3.1 The scope of works includes the following:

- Undertake a hydrological assessment to produce peak flows, which will be used as input boundaries within the new model. A copy of the Hydrological Assessment Report (SHF.1935.001.HY;.R.002.A, November 2021) is included in Appendix 1.
- Build a 1D2D linked model using detailed channel survey/LiDAR data and new hydrological peak flows to provide baseline flood outlines in order to refine existing mapped fluvial outlines and also allow the modelling of proposed flood risk mitigation measures to inform a development masterplan of the Site.

2.0 Baseline Model Methodology

2.1 Introduction

2.1.1 Hydraulic modelling is used to convert the hydrological modelling outputs (peak flows) into flow and water levels within a watercourse and its associated floodplain areas.

2.1.2 A 1D2D linked hydraulic model of Grimescar Dike was constructed by Enzygo Ltd during September and October 2021, utilising ESTRY-TUFLOW modelling software (version 2020-10-AA-iSP-w64).

2.1.3 The model files and a modelling log, which includes a model file schedule (list of all files used in the modelling), are included in Appendix 2.

2.2 Model Extent

2.2.1 A detailed channel survey of Grimescar Dike, inclusive of cross sections and in-channel structures, was undertaken in October 2021 with the below extent.

- Grimescar Dike – 0.77km survey reach length.
  - From 270m west (upstream) of Halifax Road (NGR) 411576, 418840 to 150m east (downstream) of Burn Road (NGR) 412166, 418909.

2.2.2 A copy of the detailed watercourse channel survey is included in Appendix 3.

2.2.3 The overall model extent extends from (NGR) 411576, 418840 to (NGR) 412166, 418910 and covers a total Grimescar Dike reach length of 0.77km. All of the model reach is covered by the detailed channel survey. Vegetated sections of bed were observed, although none caused access issues.

2.2.4 Vegetation was observed across the channel downstream of Burn Road, although this did not prevent a channel survey from being undertaken. From the upstream survey extent to the upstream face of Burn Road, the banks were lightly vegetated with a channel observed to be free of vegetation. In all reaches of the model, flowing water was observed.

2.2.5 Scrutiny of aerial photography in Google Earth Pro software for the period of 2002 to 2020 confirms that the Grimescar Dike channel has not spatially changed, indicating a stable channel. There are no apparent changes to the road layout and location of culverts within the vicinity of the Site, although there has been increased urbanisation within the catchment both upstream and downstream of the Site.

2.2.6 The detailed channel survey includes four in-channel structures and described the type, size (diameter, width, height, length), invert and soffit level. These details are outlined in Section 2 of this report. Photographs of the watercourse and associated structures were provided with the detailed channel survey. Key photographs are included in Table 2.1.

2.2.7 A summary of the Site boundary, modelled extent, and survey extent is included in Figure 2.1.

Figure 2.1: Model Extent



***Pink**: Model extent. **Red**: Site boundary*

2.3 Cross-Sections

2.3.1 The model includes a single reach of Grimescar Dike which has a total length of 0.77km (Figure 2.2). Cross-sections were taken from the detailed channel survey (Appendix 2) at an average interval of approximately 33m. Cross sections were taken on both the upstream and downstream faces of in-channel structures. A total of 21 sections were surveyed (Figure 2.2, overpage).

2.3.2 Of the 21 modelled cross sections, six are representative of the upstream and downstream faces of structures.

Figure 2.2: Location of Modelled Cross-Sections



Cyan: *Open channel* ***Green:*** *Irregular culvert* ***Yellow:*** *Circular culvert* ***Red:*** *Weir* ***Pink:*** *Cross section*

2.3.3 All cross-sections have been trimmed (between right and left bank top) to include only in-channel data representative of the in-channel 1D domain.

2.3.4 Modelled left and right bank levels and locations were based on the cross-section survey data.

2.3.5 All cross-sections have been modelled looking downstream (left bank to right bank).

2.3.6 All cross-sections have been modelled through layer '1d_xs_BRN_001' which links to associated cross-section csv files. The .csv files also contain varying 1D Manning's 'n' roughness values linking to .tmf file 'BRN_001.tmf' through an 'M' flag attribute.

2.4 Structures

2.4.1 The survey picked up four in-channel structures along the extent of the surveyed watercourses.

2.4.2 Identified structures comprise irregular culverts and circular culverts, the details of which are summarised in Table 2.1.

Table 2.1: In-channel Structure Photos and Descriptions (continues over page)

Structure 1 (GRIM_0330) – Halifax Road Culvert, Upstream

Left: *Looking downstream to the upstream face of Structure 1;* ***Right:*** *Looking upstream to the downstream face of Structure 1*
• Modelled as an 'C' (Circular culvert) with overtopping modelled in the 2D domain • Losses: default as per the TUFLOW manual • Opening Dimensions: 0.725m • u/s invert: 179.66mAOD (informed from bounding cross sections) • d/s invert: 177.10mAOD (informed from bounding cross sections and calculated based on a linear gradient between cross section GRIM_0616 and GRIM_0507) • Length: 40.73m • Manning's: 0.012 (representative of concrete, cement - finished).

Structure 2 (GRIM_0507) – Halifax Road Culvert, Downstream



Looking upstream to the downstream face of Structure 2

- Modelled as 'I' (irregular culvert) with overtopping modelled in the 2D domain
- Losses: default as per the TUFLOW manual
- Opening Dimensions: cs layer – Culvert_2.csv (informed from GRIM_0507)
- u/s invert: 177.10mAOD (informed from bounding cross sections and calculated based on a linear gradient between cross section GRIM_0303 and GRIM_0289)
- d/s invert: 174.60mAOD (informed from bounding cross sections)
- Length: 40.73m
- Manning's: 0.015 (representative of masonry).

Structure 3 (GRIM_0330) – Ø1.90m Circular Culvert



Downstream face of Structure 3

- Modelled as an 'C' (Circular culvert) with overtopping modelled in the 2D domain
- Losses: default as per the TUFLOW manual
- Opening Dimensions: 1.90m
- u/s invert: 165.87mAOD (informed from bounding cross sections)
- d/s invert: 165.51mAOD (informed from bounding cross sections)
- Length: 10.06m
- Manning's: 0.021 (representative of corrugated steel).

Structure 4 (GRIM.0507) – Burn Road Culvert



Looking downstream to the upstream face of Structure 4

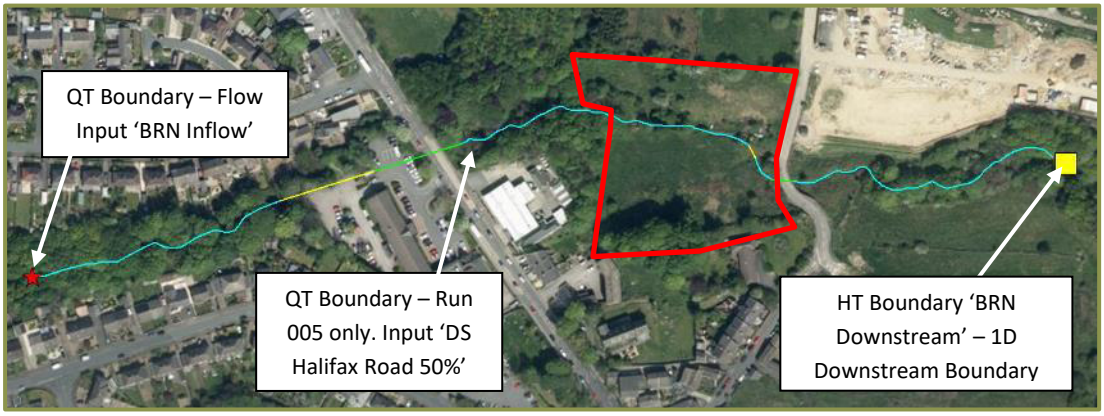
- Modelled as an 'I' (Irregular culvert) with overtopping modelled in the 2D domain
- Losses: default as per the TUFLOW manual
- Opening Dimensions: cs layer – Culvert_4.csv (informed from GRIM_0303)
- u/s invert: 165.43mAOD (informed from bounding cross sections)
- d/s invert: 164.46mAOD (informed from bounding cross sections)
- Length: 14.21m
- Manning's: 0.012 (representative of Concrete)

2.5 Inflow Boundaries

2.5.1 The Hydrological Assessment Report; SHF 1935.001.HY.R.001.A (Appendix 1) details the hydrological assessment to derive peak flow inputs and hydrographs for a single flow calculation location on Grimescar Dike (Figure 2.3).

2.5.2 Hydrological peak flows have been input into the model at a single input location at the upstream extent of the 1D model domain using layer '1d_bc_BRN_Flows_001' (BRN Inflow). Flows have been input as a 'QT' boundary (Flow Time). For Run 005, a second inflow point called 'DS Halifax Road 50%' through layer '1d_bc_BRN_Flows_001'' was input at the downstream extent of Culvert 2 to represent overland flow shown in Figure 1.3. This approach assumes that the surface water flow pathway comprises 50% of the calculated flow for the Grimescar Dike catchment

Figure 2.3: Peak Flow Calculation and Input Locations



2.5.3 A Climate change allowance of 31% and 51% has been applied to the 1 in 100-year flow estimate representing the 'Higher Central' and 'Upper End' estimate for the Total Potential Change for the 2080s (2070 to 2115) for the Aire and Calder Management Catchment.

2.5.4 A summary of the peak flows for all return periods are included in Table 2.3.

Table 2.3: Peak Flows Used in the Modelling Study

Return Period (yr)	Peak Flows (m^3/s)
20	0.868
100	1.355
1000	2.627
*100 + (31%CC)	1.775
*100 + (51%CC)	2.046

*Climate change Peak flow allowances for the Aire and Calder Management Catchment: Higher Central and Upper End (2070 – 2115)

2.6 Downstream Boundary

2.6.1 The downstream 1D boundary has been input via layer '1d_bc_BRN_Flows_001', as a 'HT' (Level Time) boundary.

2.6.2 At the downstream model extent, a weir channel (Model_Out) has been created with an upstream invert of 152.38mAOD (corresponding to XS GRIM_0118.csv), downstream invert of 148.50mAOD and Manning's roughness of 0.02. The weir channel conveys to the downstream HT boundary with a fixed water level of 149.00mAOD. Utilisation of a weir channel at the downstream extent of the 1D network is an efficient and stable method to allow in channel

flow to exit the model. Any drawdown impacts as a result of critical depth are limited to the downstream extent of the model.

2.6.3 The use of a weir ensures that impacts of an arbitrary fixed water level do not impact upon modelled outlines or in channel levels.

2.6.4 A 2D boundary has been applied through the layer '2d_bc_BRN_BNDY' to allow overland flow to freely exit the 2D model domain without glass walling. 2D boundaries have been applied at the following locations:

- **Location:** 412167, 418911 to 412174, 418961 **Name:** Downstream A **Type:** HQ **'b' Attribute/slope factor:** 0.111
- **Location:** 412164, 418907 to 412143, 418845 **Name:** Downstream B **Type:** HQ **'b' Attribute/slope factor:** 0.111

2.7 Hydraulic Roughness

2.7.1 Hydraulic roughness represents the conveyance capacity of, vegetation growth, bed and bank material, channel sinuosity and structures and land use within the floodplain. Within ESTRY-TUFLOW, the hydraulic roughness is defined using the Manning's 'n' roughness coefficient values. Table 2.4 contains photographs showing typical channel roughness within the model extent.

2.7.2 Manning's 'n' roughness values were assigned from survey and photographs, modelling judgement and through industry standard literature including Chow, Hicks & Mason and USGS. Chow (1959) contains reference tables to match observed bed conditions with a value for Manning's 'n'. These reference tables are the most widely used method in 1D hydraulic modelling.

2.7.3 Manning's roughness values have been input through use of the 'M' flag in the 'XS' layer, multiplier in the 'nwke' layer and tmf (BRN_001.tmf) Manning's codes applied in the XS.csv files. Use of this method allows application of varying Manning's values to represent in changes in roughness within a cross section.

Table 2.4: Grimescar Dike Manning's Roughness

Grimescar Dike Manning's Roughness



Left: *Looking upstream from GRIM_0771 (Manning's of 0.040 banks and 0.035 channel)*

Right: *Looking upstream from GRIM_0736 (Manning's of 0.040 banks and 0.035 channel)*



Left: *Looking upstream from GRIM_0413 (Manning's 0.040 banks and 0.045 channel)*

Right: *Looking upstream from GRIM_0384 (Manning's 0.060 left bank, 0.045 right bank, and 0.045 channel)*



Left: *Looking upstream from GRIM_0156 (Manning's of 0.040 banks and 0.035 channel)*

Right: *Looking downstream from GRIM_0172 (Manning's 0.040 banks and 0.045channel)*

2.7.4 The majority of Grimescar Dike comprises vegetated banks, with varying density, and a natural gravel bed with a roughness of between 0.035 and 0.045 which is representative of a 'Natural stream which is clean, winding, some pools and shoals. Steam bed consists of stones and cobbles*'* and *'Natural stream which contains increased weeds, pools and shoals'*.

2.7.5 The Manning's 'n' roughness coefficient value for the left and right banks within the 1D domain ranged between 0.025 (*Rubble masonry, cemented [normal]*) and 0.060 (*Thickly vegetated banks consisting of scrub and weeds*).

2.7.6 Scrutiny of the model extent using OS mapping, aerial photographs and walkover photographs showed that significant areas were grassed. As such, a base value of 0.045 representing 'General Surface Natural' was utilised within the model. Further layers representing roughness for various land uses have been added, namely:

- 2d_MAT_BRN_Roads_Tracks_Hardstanding_001 (Manning's value of 0.04)
- 2d_MAT_BRN_Gardens_001 (Manning's value of 0.05)
- 2d_MAT_BRN_Buildings_001 (Manning's value of 0.05)
- 2d_MAT_BRN_ Trees_and_Shrubs_001 (Manning's value of 0.10)

2.8 Flow Constrictions

2.8.1 Buildings have been represented in layer '2d_fcsh_BRN_Buildings_001' as flow constrictions, with a 90% constriction value. Use of a 90% constriction is considered a default value, representative of typical buildings. Building representation as 'flow constrictions' is considered to better replicate overland flow paths in and around built-up areas when compared to using increased Manning's 'n' roughness values[1].

[1] Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences, W J Syme

2.9 Topographic Changes

2.9.1 Layer '2d_ztin_BRN_Site_001' defines the topography of the Site, with this being represented in the 2D domain. This layer applies spot height levels from the topographical survey.

2.9.2 Layer '2d_zsh_BRN_Patches_001' has been used to define ground levels where they may need reinforcing in the 2D domain. This layer applies levels observed to 'flatten' out the ground when they have been 'filtered' incorrectly from the 1m DTM LiDAR.

2.9.3 Layer '2d_zsh_BRN_Stability_Patches_001' has been used to define ground levels where they may need reinforcing in the 2D domain that would otherwise cause instability in the model. This layer applies levels observed to 'flatten' out the ground when they have been 'filtered' incorrectly from the 1m DTM LiDAR

2.9.4 Layer '2d_zsh_BRN_Decks_001' has been used to define road level and structure decks where structures have been represented in the 2D domain. This layer applies levels from the topographical and channel survey to reinstate structure decks that have been 'filtered' from the DTM LiDAR.

2.9.5 Layer '2d_ZLN_BRN_Parapets_001' defines surveyed ground levels at Halifax Road, the location of Culvert 1 to accurately represent spill levels if flood water was to overtop onto Halifax Road.

2.10 Model layers

1D Model Layers

- 1d_xs_BRN_001; defines cross-section locations (Baseline)
- 1d_cs_BRN_001; defines irregular culvert openings
- 1d_cs_BRN_002b; defines irregular culvert openings with 50% blockage on Culvert 4 – used in initial build, now deemed a redundant layer
- 1d_cs_BRN_002c; defines irregular culvert openings with 50% blockage on Culvert 4
- 1d_nwke_BRN_001; defines in-channel network (Baseline)
- 1d_nwke_BRN_002a; defines in-channel network (Baseline) with a 50% blockage of Culvert 1
- 1d_nwke_BRN_004a; defines in-channel Manning's roughness increase of 20%
- 1d_nwke_BRN_004b; defines in-channel Manning's roughness decrease of 20%
- 1d_bc_BRN_Flows_001; defines fluvial inflows and HT downstream boundary
- 1d_bc_BRN_Flows_003a; defines downstream boundary increase
- 1d_WLL_BRN_001; defines in-channel water level lines (Baseline)

2D Model Layers

- 2d_bc_hx_BRN_001; defines 1D2D linking cells (Baseline)
- 2d_code_BRN_001; defines model extent
- 2d_bc_BRN_BNDY_001; defines floodplain boundaries to prevent glass walling
- 2d_code_1d_BRN_001; defines 1d channel domain (Baseline)

2D Topographical Layers

- 2d_ztin_BRN_Site_001; defines the site levels from topographic survey
- 2d_zsh_BRN_Patches_001; defines values for a LIDAR patch fix within the 2D model domain.
- 2d_zsh_BRN_Stability_Patches_001; defines values for a LIDAR patch fix to increase model stability within the 2D model domain.
- 2d_zsh_BRN_Decks_001; defines values for bridge decks associated with culverts;
- 2d_ZLN_BRN_Parapets_001; defines parapets associated with bridge decks;
- 2d_fcsh_BRN_Buildings_001; defines buildings through flow constriction layer. A 90% constriction has been applied
- 2d_MAT_BRN_Roads_Tracks_Hardstanding 001; defines 2D roughness for roads, tracks and car parks
- 2d_MAT_BRN_Buildings_001; defines roughness for buildings
- 2d_MAT_BRN_Gardens_001; defines roughness for gardens
- 2d_MAT_BRN_Trees_and_Shrubs_001; defines 2D roughness for wooded areas
- 2d_MAT_BRN_Roads_Tracks_Hardstanding_004a; defines 20% roughness increase for roads, tracks and car parks
- 2d_MAT_BRN_Buildings_004a; defines 20% roughness increase for for buildings
- 2d_MAT_BRN_Gardens_004a; defines 20% roughness increase for gardens
- 2d_MAT_BRN_Trees_and_Shrubs_004a; defines 20% roughness increase for wooded areas
- 2d_MAT_BRN_Roads_Tracks_Hardstanding_004b; defines 20% roughness decrease for roads, tracks and car parks
- 2d_MAT_BRN_Buildings_004b; defines 20% roughness decrease for buildings
- 2d_MAT_BRN_Gardens_004b; defines 20% roughness decrease for gardens
- 2d_MAT_BRN_Trees_and_Shrubs_004b; defines 20% roughness decrease for wooded areas

2.11 Model Runs

2.11.1 The 1D2D linked ESTRY-TUFLOW hydraulic model was run for a range of return periods, using peaks flows from the Hydrological Assessment Report, which are summarised in Table 2.2.

2.11.2 A 1D timestep of 0.25 seconds, a 2D timestep of 0.5 second and 2D grid size of 1m were chosen. These parameters are in-line with industry standard guidance for grid sizes and timesteps where the 2D timestep should be ½ to ¼ of the grid size and the 1D timestep should be ½ to ¼ of the 2D timestep. A simulation time of 6-hours was also selected to allow the flood peak to pass through the model and ensure the maximum extent of flooding was captured.

2.11.3 The model was run for the following return periods; 20-year, 100-year and 1000-year.

2.11.4 The model also was run with a 31% and 51% allowance for climate change for the 1 in 100-year event, representative of the Higher Central and Upper End estimate for the Aire and Calder Management Catchment (2070 - 2115).

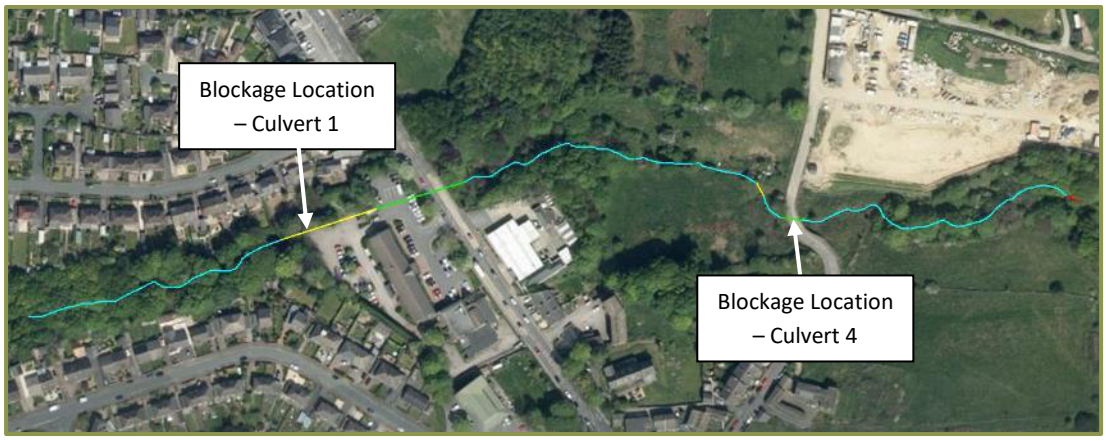
2.11.5 Blockage analysis was carried out using the 1 in 100-year event in which a blockage was applied to the following structures:

- Culvert 1 (Channel ID: Culvert_1) – This is a 'C' culvert opening. A 'pBlockage' value of 50 was applied to represent a 50% blockage of the culvert. This is considered appropriate based on the properly designed and installed trash screen at the upstream extent of Culvert 1.
- Culvert 4 (Channel ID: Culvert_4) – This is an irregular 'I' culvert opening, so blockage was applied through csv file 'Culvert_4_002b'. The width of the HW irregular culvert opening was reduced by 50% was considered appropriated based on the structure opening dimensions.

2.11.6 The blockage locations have been chosen based on the likely impact upon the development Site. Blockage of Culvert 1 could result in overtopping onto Halifax Road, with subsequent overland flow towards the Site whilst blockage of Culvert 4 could increase afflux with elevated flood levels within the Site.

2.11.7 A 50% blockage was applied as this represents significant but realistic structure blockage based upon the structure opening dimensions and likelihood of blockage. The blockage locations are shown in Figure 2.4 (overpage).

Figure 2.4: Blockage Location



2.11.8 Sensitivity analysis was carried out using the 1 in 100-year event to show a worst-case scenario, which includes +/-20% Manning's 'n' (to allow for seasonal changes in vegetation) and increase to the downstream boundary by +0.50m.

2.11.9 Run 005 includes a second inflow location, downstream of Culvert 2, to represent the overland flow pathway shown in Figure 1.3. The overland flow pathway shows that some flow, emanating from the Grimescar Dike catchment, could by-pass Culvert 1 (Halifax Road) and enter Grimescar Dike downstream of the structure. The flow pathway would not be subject to any attenuating/storage impacts resulting from reduced Culvert 1 conveyance capacity. Run 005 was run for the 1 in 1000-year event only in which the peak flow hydrograph (peak of 2.627 m^3/s) was split 50/50 between inflow points 'BRN_Inflow' and 'DS Halifax Road 50%'.

2.11.10 Table 2.5 and the modelling log (Appendix 2) provide a summary of all model runs undertaken.

Table 2.5: Run Identifiers and Description (Baseline)

Model Run ID	Scenario Description
~e~_001	Existing free-flowing structures (Baseline)
~e~_002a	Existing 50% culvert blockage (Culvert 1)
~e~_002b	Existing 50% culvert blockage (Culvert 4)
~e~_003a	Downstream Boundary +0.5m
~e~_004a	Mannings Roughness +20%
~e~_004b	Mannings Roughness – 20%
~e~_005	50% inflow downstream of Halifax Road Culvert

3.0 Analysis of Results

3.1 Summary of Model Outputs

Baseline Scenario (001)

3.1.1 Figure 3.1 shows the maximum flood extents for the whole model domain. The baseline flood extents are also provided as Drawing 001.

3.1.2 The model results shown that the Site is largely unaffected by flooding (Figures 3.1 and 3.2. The Site is shown to not be affected by the 1 in 20-year, 1 in 100-year and 1 in 100-year+31%CC events where floodwater remains in channel. The flood extent associated with the 1 in 100-year+51%CC event and 1 in 1000-year shows a small area of flooding, adjacent to Grimescar Dike in the western Site extent, before floodwater re-enters the channel.

3.1.3 For all modelled events, except the 1 in 20-year event, there is surcharging of Culvert 1, upstream of the Site and under Halifax Road resulting in afflux and storage of floodwater. However, the water is contained within the steep banks associated with Grimescar Dike and does not result in any overland flow.

Figure 3.1: Baseline Flood Outlines



***Red**: Development Site Boundary*

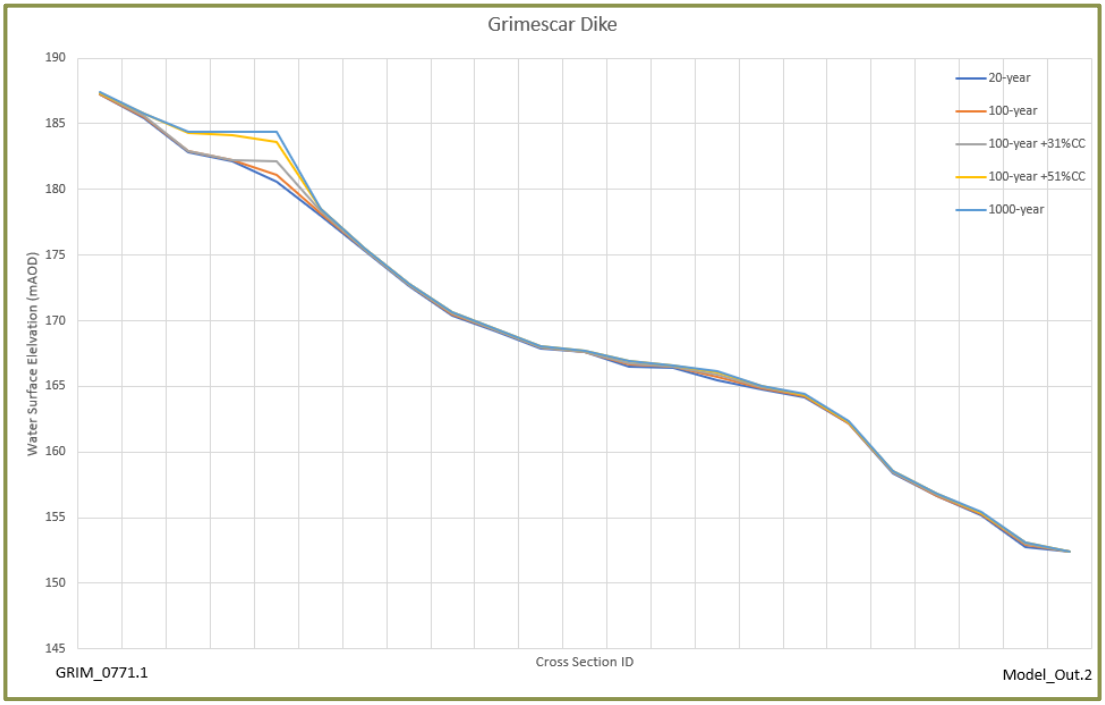
Figure 3.2: Baseline Flood Outlines - Site



***Red**: Development Site Boundary*

3.1.4 Figure 3.3 provides a summary of the maximum flood levels within the modelled watercourses for the range of return periods during Run 001 (Baseline). Full tabulated results have been included in Appendix 4. Modelled water surface profiles are consistent and increase with return period as would be expected. The afflux upstream of Culvert 1 is clearly visible with little variation in flood level within the Site.

Figure 3.3: Baseline In-channel Flood Levels



3.1.9 Baseline results show that the Halifax Road culvert (Culvert 1) has a constraining impact upon peak flow inputs which result in increased upstream afflux and storage. Table 3.1 shows the peak flow input and maximum downstream of Culvert 2.

Table 3.1: Peak Flow input and Maximum Culvert 1 Flow

Return Period	Peak flow input (m^3/s)	Culvert 1 maximum flow (m^3/s)	Percentage reduction (%)
1 in 20-year	0.868	0.856	1
1 in 100-year	1.355	1.345	1
1 in 1000-year	2.627	2.380	9
1 in 100-year +31%	1.775	1.755	1
1 in 100-year +51%	2.046	2.003	2

3.1.10 Table 3.1 shows that Culvert 1 reduces input peak flow by 1 to 9%. For events between the 1 in 20-year and 1 in 100-year +51%CC, Culvert 1 impact on flows is negligible. In the 1 in 1000-year worst case event, input peak flows are reduced by 9% which shows that Culvert 1 has a low impact on peak flows reaching the Site.

Blockage Scenario (002a and 002b)

3.1.11 Figures 3.4, 3.5 and Appendix 4, provide a summary of the maximum flood levels and extents for the structure blockage scenario.

3.1.12 When a 50% blockage is applied to Culvert 1, the following impacts are seen:

- Culvert 1 (Run 002a): An increased flood outline upstream Culvert 1, due to the surcharging of the structure causing upstream afflux and storage. There is an increase in in-channel levels by a maximum of +2.88m upstream and at the location of Culvert 1. There is no creation of additional flow pathways as a result of a 50% blockage of Culvert 1. There model results show that the Site and the remainder of the model domain is not affected.
- It should be noted that due to instability in the Run 002a, a stability patch was inserted upstream of Culvert 1, as such there is a slight variation in the outline provided before flows enter Culvert 1.

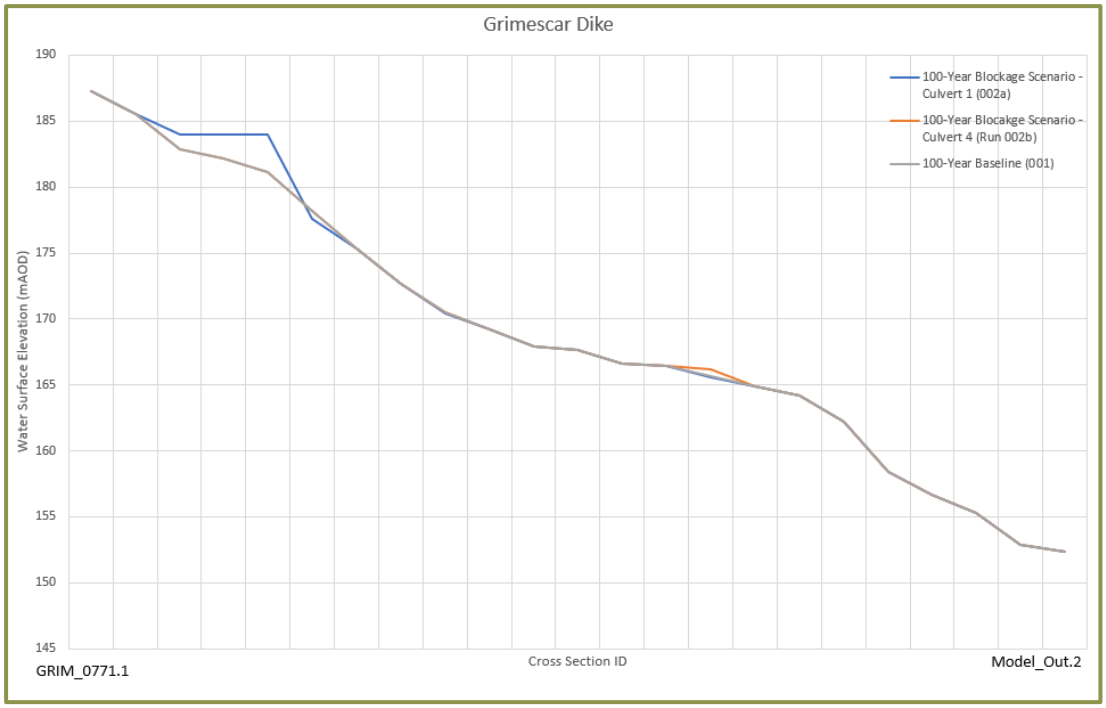
3.1.13 When a 50% blockage is applied to Culvert 4, the following impacts are seen:

- Culvert 4 (Run 002a): There is no visible change to the flood extent associated with a 50% blockage of Culvert 4 and no impact to the Site. The 1D in-channel levels associated with Culvert 4 blockage increase by +0.51m upstream of the Culvert 4 inlet.

Figure 3.4: Flood Outlines - Blockage Scenario Flood Outlines



Figure 3.5: Blockage In-channel Flood Levels (Runs 002a and 002b)

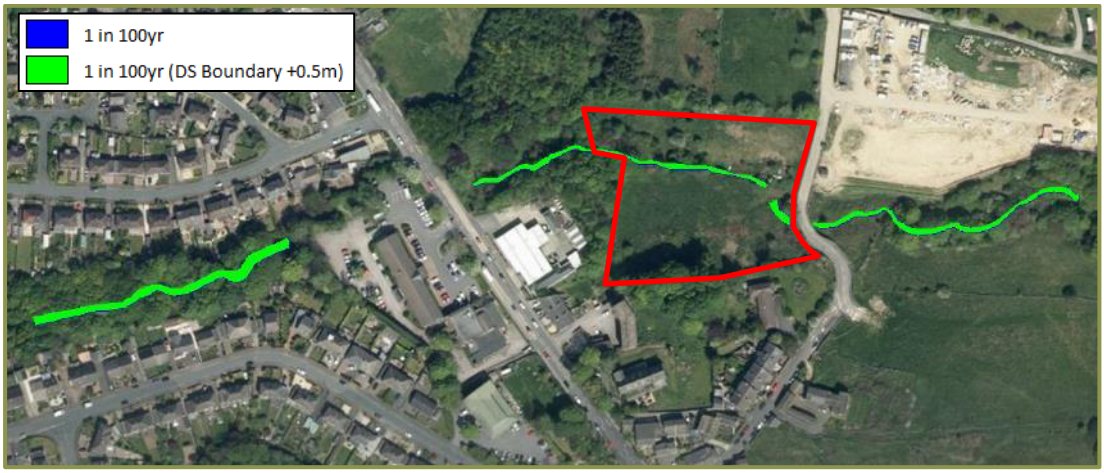


Downstream Boundary Sensitivity (003a)

3.1.12 This section provides a summary of the 1 in 100year event modelled water levels when the downstream modelled water level is increased by +0.50m (Figures 3.6 and 3.7).

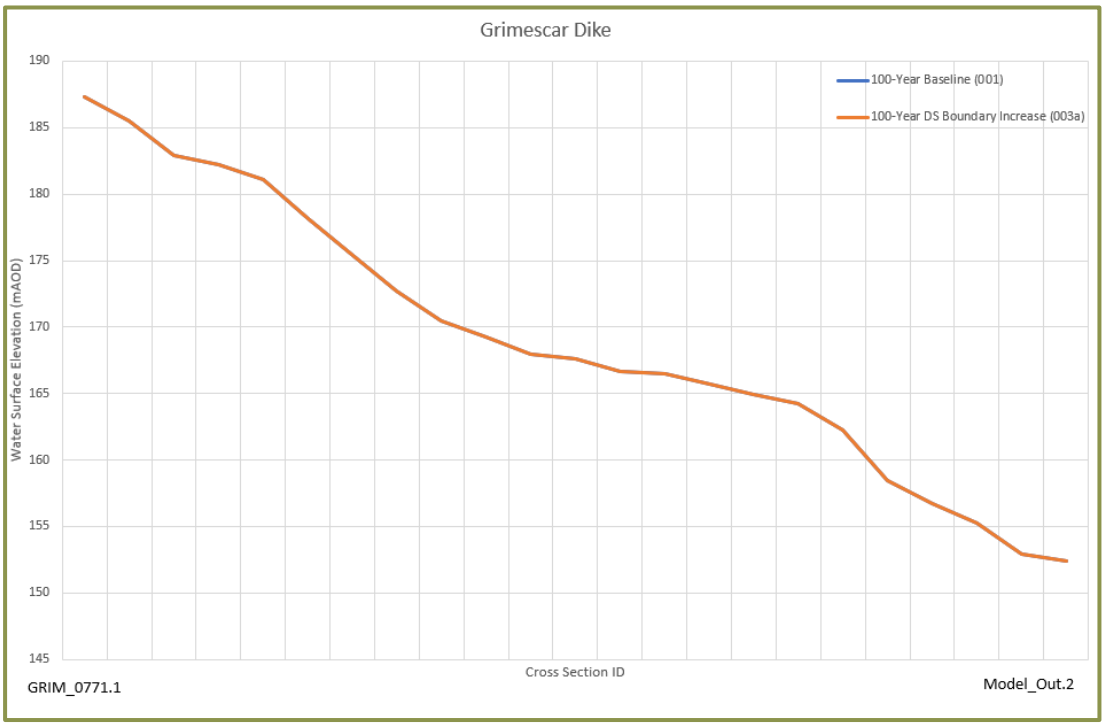
3.1.13 When the downstream water level is increased by +0.50m to 149.50mAOD, there is no change in levels for the entirety of the model (Figure 3.6, 3.7 and Appendix 4). The model is insensitive to changes to the downstream boundary.

Figure 3.6: Downstream Boundary Sensitivity (Runs 003a)



***Red**: Development Site Boundary*

Figure 3.7: Downstream Boundary Sensitivity In-channel Flood Levels (Run 003a)



3.1.14 The above assessment has demonstrated that flood extents within the Site are not sensitive to downstream boundary changes. This is as expected as cross section GRIM_0118, representing the model downstream extent, is at 152.38mAOD, which is 12m below the downstream channel level within the Site (Cros section GRIM_0303).

Manning's 'n' Sensitivity (004a and 004b)

3.1.16 When Manning's 'n' roughness values are increased by 20%, in-channel water levels within the model exhibit an average increase of 0.03m, with a maximum increase of 0.05m at nodes GRIM_0458.2 and GRIM,0289.1 (Figure 3.8, 3.9 and Appendix 4). In-channel water level

increase results in a negligible increase in flood extents throughout the model. Grimescar Dike appears largely insensitive to manning's increase.

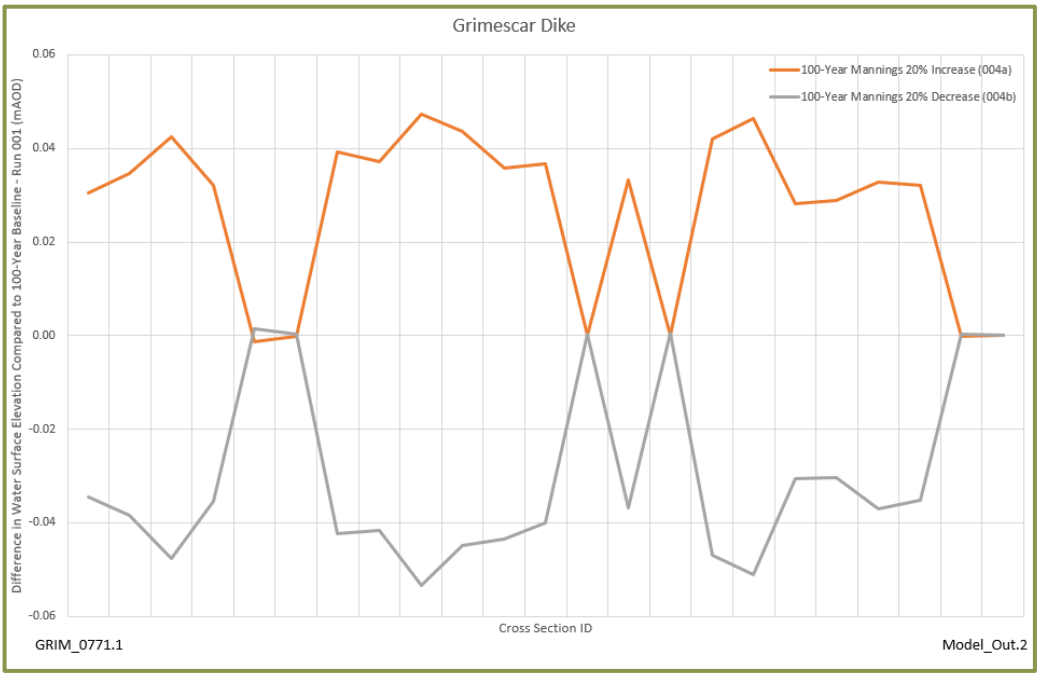
3.1.17 When Manning's 'n' roughness values are decreased by 20%, in-channel water levels within the model exhibit an average decrease of -0.03m, with a maximum decrease of 0.05m at nodes Culvert 1.1, GRIM_0458.2, and Culvert 4.2 (Figure 3.8, 3.9 and Appendix 4). In-channel water level decrease results in a negligible decrease across the Site. Grimescar Dike appears largely insensitive to manning's decrease.

Figure 3.8: Modelled Flood Extents (+/-20% Manning's 'n')



***Red**: Development Site Boundary*

Figure 3.9: Manning's Sensitivity Differences in In-channel Flood Levels Compared to 100-Year Baseline (004a and 004b)



3.1.18 Manning's sensitivity results are as expected, with increase and decrease in level and extent when roughness is increased and decreased respectively. The degree of in channel level change (+0.03m and -0.03m for Runs 004a and 004b) increases confidence in model behaviour.

50% flow distribution (Run 005)

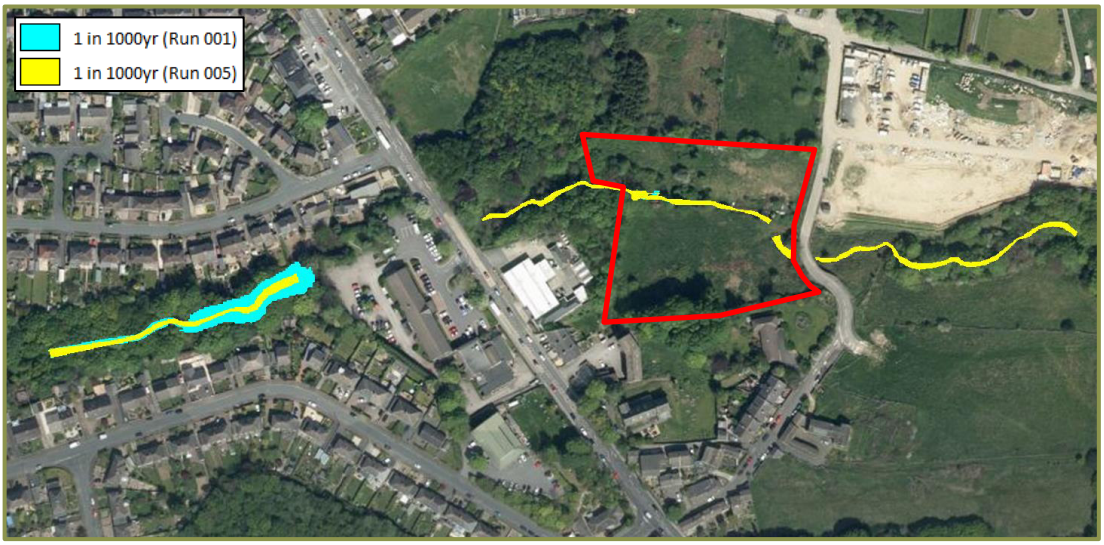
3.1.19 When the input peak flow is split between input 'BRN_Inflow' and 'DS Halifax Road 50%' water levels upstream of Halifax Road reduce by -1.72m and increase by 0.19m downstream of Halifax Road during the 1 in 1000-year event. Maximum Culvert 1 peak flow is 1.309m^3/s, and with the additional 1.3097m^3/s input at 'DS Halifax Road 50%' the peak flow entering the Site increases by 0.30m^3/s when compared to the baseline 1 in 1000-year event.

3.1.20 The increase in peak flow of 0.3m^3/s results in increased flood extent in the western area of the Site. This is expected as limited flooding is shown at this location in both the 1 in 100-year +51%CC and 1 in 1000-year baseline events.

3.1.21 Run 005 has demonstrated that the impact of the surface water flow pathway shown to enter Grimescar Dike, downstream of Culvert 2, is limited to a small area in the western Site extent (Figure 3.10). There is no impact upon flood extents in the rest of the Site, or model domain.

3.1.22 Appendix 4 shows that redistribution of input peak flows to account for the surface water flow pathway increases in-channel flood level within the Site by an average of +0.09m and maximum of 0.50m at cross section Culvert 4.1.

Figure 3.10: Model Extents for inflow redistribution (005)



Sensitivity Analysis Summary

3.1.19 Sensitivity analysis and blockage analysis has shown that the watercourse is largely insensitive with only negligible increases/decrease in flood extent. Flood outlines are most sensitive to blockage of Culvert 1 but extents within the Site are unaffected.

3.1.20 The model displays negligible sensitivity to manning's roughness and downstream boundary changes. No change is seen within the Site redline boundary, or at any point along the modelled reach.

3.1.21 The choosing of hydraulic parameters can often be subjective and parameters such as Manning's roughness can undergo seasonal change through vegetation growth. The sensitivity

analysis increases confidence in the modelled results through identifying that changes due to subjective parameter choices are limited to the eastern pathway or southern extent within the Site boundary.

Message Layers

3.1.5 Negative depth warnings are present during all model runs (Figure 3.11). However, these only occur within the space of 2 minutes (at times 1hr 5mns, 1hr 25mins and 1hr 40mins) at cross section GRIM_0061, which is upstream of Halifax Road. The negative depths occur when afflux is increased due to surcharging of Culvert 1 and floodwater storage occurs upstream of Halifax Road. The location of the negative depths, short duration and occurrence approximately 1hr before the inflow hydrograph peak will have negligible impact on resultant flood extents and parameters.

Figure 3.11: Model Warning Messages (All Baseline model runs)

Message	Wiki_Link
CHECK 1152 - For channel Culvert2, using centre cross-section and ignoring end cross-section(s).	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1152
CHECK 1152 - For channel Culvert 4, using centre cross-section and ignoring end cross-section(s).	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1152
CHECK 1152 - For channel Model_Out, using centre cross-section and ignoring end cross-section(s).	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1152
WARNING 1100 - Structure Culvert2 crest/invert (174.600) is below bed (174.960) of primary downstream channel GRIM_0507.	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1100
WARNING 1100 - Structure Culvert 3 crest/invert (165.870) is below bed (166.200) of primary upstream channel GRIM_0359.	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1100
WARNING 1100 - Structure Culvert 3 crest/invert (165.510) is below bed (166.110) of primary downstream channel GRIM_0346.	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1100
WARNING 1991 - 1:39:01: Negative depth at Node GRIM_0661A.1: y = -2.61 Bed = 181.88 dh = -2.68	https://wiki.tuflow.com/index.php?title=TUFLOW_Message_1991

3.1.6 An assessment of the warning and check messages is included below:

- Check 1152: refers to the use of the CS layers to culvert openings. All messages have been checked and are as expected.
- Warning 1100: this message relates to the crest/invert of a structure being below the bed of the upstream or downstream bed of the channel. The messages have been checked against the 'nwke' layer and detailed survey and are as intended.
- Warning 1991: this relates to a numerical solution resulting in a negative depth at the 1D node. This was only observed over the course of approximately 2 minutes (multiple negative depths were observed) during the model run, and as such is not considered to cause an issue within the model outputs.

3.2 Mass Balance Error

3.3.1 The TUFLOW User Manual states that a healthy model should display less than a ±1% error or 2 or 3% depending on the objectives of the modelling. During model reviews, the Environment Agency adopts a ±2% threshold for acceptability. For this model a threshold of ±2% was adopted, due to the steep catchment.

3.3.2 On all runs, cumulative and 1D mass error is above +/-2%. Any peaks for within the model runs above +/-2% is associated with initial model wetting and will not impact upon results. 2D error peaks between -1.9% and +2.0% during all runs. Mass balance error is within the acceptable threshold for all model runs (Table 3.2).

Table 3.2: Mass Balance Error

Model Run	Maximum Cumulative Error (%)	Maximum 1D Error (%)	Maximum 2D Error (%)
20yr	0.0 to 2.0% from start to 56mins 30secs. 2.1% from 56mins 31secs to 1hr 11mins 4secs. 2.0% or below from 1hr 11mins 5secs to end	0.0 to 2.0% from start to 1hr 32mins 41secs. 2.1% or above from 1hr 32mins 42secs to 1hr 42mins 20secs. 2.0% or below from 1hr 42mins 21secs to end	0.0% from start to end
100yr	Between 0.0% and 1.9% from start to end	Between 0.0% and 1.8% from start to end	0.0% to -0.1% from start to end
100yr+31% Climate Change	Between 0.0% and 1.5% from start to end	Between 0.0% and 1.4% from start to end	0.0% from start to end
100yr+51% Climate Change	0.0 to 1.5% from start to 1hr 10mins 8secs. Between 1.5% and 0.3% from 1hr 10mins 9secs to end	0.0 to 1.2% from start to 1hr 10mins 6secs. Between 1.2% and 0.3% from 1hr 10mins 7secs to end	0.0 to -1.9% from start to 2hrs 3mins 12secs. Between -1.9% and -1.0% from 2hrs 3mins 13secs to end
1000yr	0.0 to -1.8% from start to 52mins 16secs. Above -1.8% from 52mins 17secs to end	0.0 to -1.8% from start to 53mins 24secs. Above -1.8% from 53mins 25secs to end	0.0 to -1.2% from start to 1hrs 43mins 40secs. Between -1.2% and -0.1% from 1hrs 43mins 41secs to end

3.3.3 The TSMB1D2D results file, which represents error within linking cells, can be used to spatially locate cumulative mass error in situations where areas of instability are not evident. TSMB1D2D files were checked for all model runs. No significant error was shown within the files for all model runs.

3.3.4 The model is stable, with no fluctuation in ‘Qi’, ‘Qo’ or ‘Dvol’, which represents the variation between inflow and outflow volumes.

3.3.5 It is considered that the constructed model is healthy and representative.

4.0 Baseline Flood Mapping

4.1 Methodology

4.1.1 Flood depth mapping was undertaken within MapInfo software. As the model is a 1D2D linked model, results are produced for the out-of-bank floodplain based upon the underlying 2m grid derived from 1m DTM LiDAR data. Results were produced in 'xmdf' format and imported into MapInfo, where the results were mapped and contoured.

4.1.2 The purpose of this modelling exercise is to fix surface water flood outlines, representative of fluvial flooding from Grimescar Dike to confidently determine fluvial flood extents in the development Site. Contouring of the results allows the production of Flood Zones; 3a (1 in 100-year), 3b (functional floodplain based upon the 1 in 20-year results) and 2 (1 in 1000-year).

4.1.3 Flood Zone 3 outlines were also produced to represent flood risk to the Site for the lifetime of the development for the 1 in 100-year plus 31% and 51% climate change event. The contoured and mapped results are presented in Figures 4.1 to 4.2 and Drawing 001.

4.1.4 Model flood extents were cleaned by using the following criteria:

- Dry islands and polygons smaller than 200m^2 were removed from the outlines;
- Polygons disconnected from the watercourse or surrounding the flood outline where there is no flow path were removed.

Figure 4.1: Modelled Flood Extents (Baseline Scenario – Model Extent)



***Red**: Development Site Boundary*

Figure 4.2: Modelled Flood Extents (Baseline Scenario – Site Extent)



***Red**: Development Site Boundary*

4.2 Reality Check

4.2.1 Figures 4.3 and 4.4 present Environment Agency surface water mapping and Enzygo modelled flood outlines for the 100-year (Flood Zone 3) and 1000-year events (Flood Zone 2). Fluvial flood outlines (Environment Agency Flood Map for Planning) are not present for the model reach so no outlines are available for comparison.

Environment Agency Surface Water Flood Mapping

4.2.2 Scrutiny of Environment Agency surface water Mapping with OS mapping and LIDAR shows that the surface water outlines reflect the topography of the existing channel, which is contained within steep banks on either side. The surface water mapping appears to account for Halifax Road and Burn Road culverts at the west and east of the Site respectively. For both the Environment Agency 1 in 100-year and 1 in 1000-year surface water mapping, there seems to be no representation of the existing circular culvert in the eastern extent of the Site (Culvert 3), as flows exceed and then re-enter the watercourse downstream of Culvert 3.

4.2.3 A comparison of Environment Agency 1 in 100-year surface water mapping (medium risk) and modelled 1 in 100-year flood extent for Grimescar Dike shows that flood extents are largely reduced across the Site and model extent (Figure 4.3). This likely due to the Grimescar Dike channel being underrepresented in the coarse grid used in the surface water mapping. Additionally, there is a surface water flow pathway which is shown on Environment Agency mapping to enter Grimescar Dike downstream of the Culvert 2 outlet.

4.2.4 A comparison of Environment Agency 1 in 1000-year surface water mapping (low risk) and modelled 1 in 1000-year flood extent for Grimescar Dike shows that flood extents are reduced across the Site and the entire model extent (Figure 4.4). As detailed above, there is a surface water flow pathway which is show on Environment Agency mapping to enter Grimescar Dike downstream of the Culvert 2 outlet. The impacts of this flow pathway were assessed through sensitivity Run 005 which demonstrated limited sensitivity to flood extents within the Site.

Figure 4.3: Environment Agency Surface Water Mapping (Medium Risk – 100-year event)

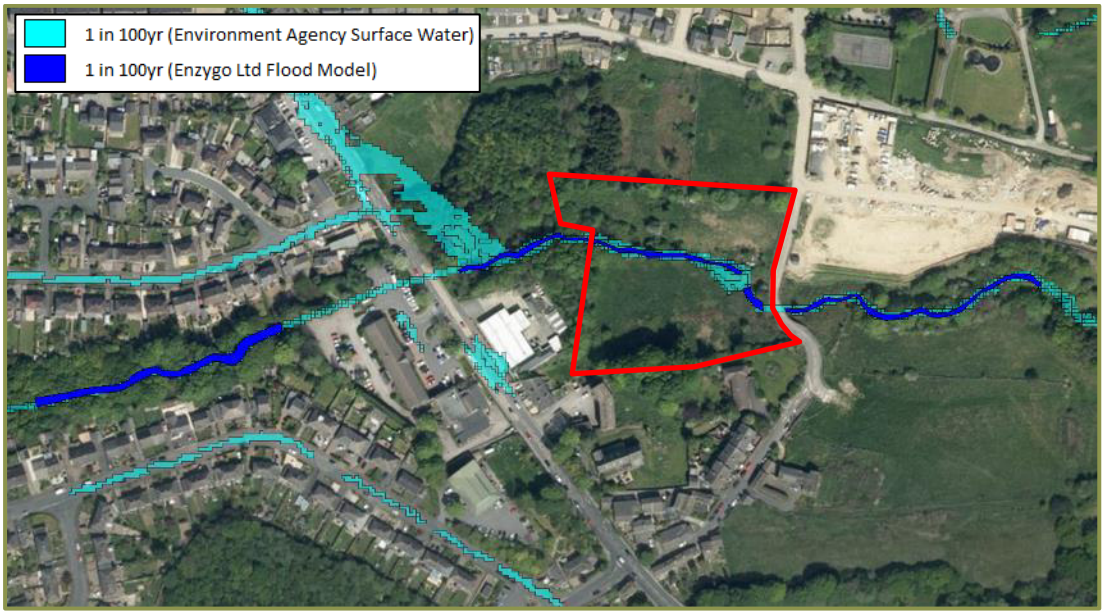
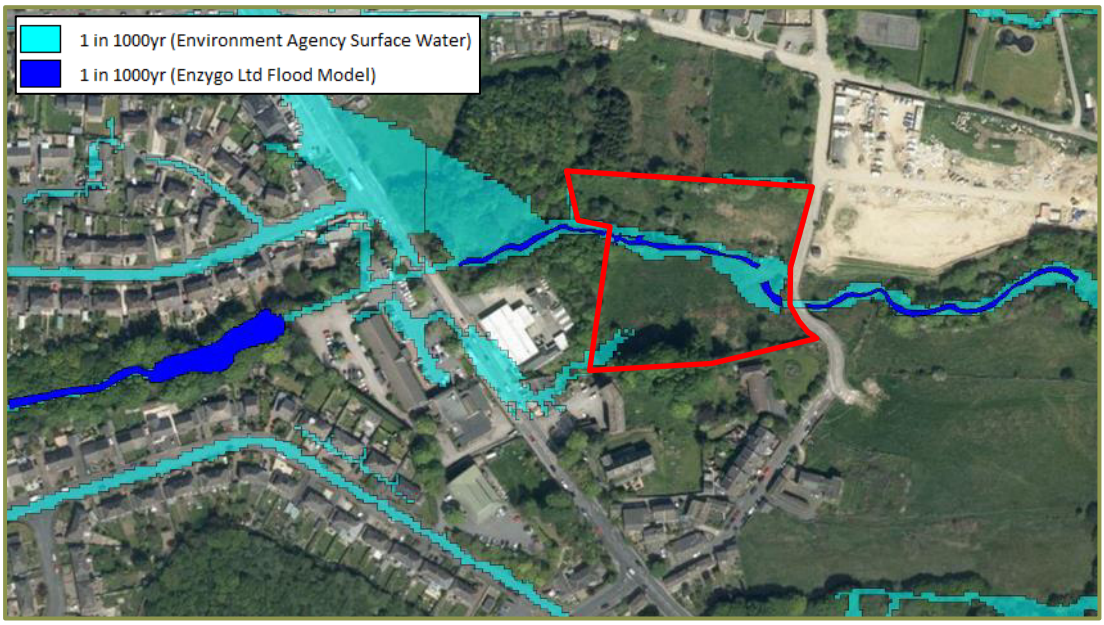


Figure 4.4: Environment Agency Surface Water Mapping (Low Risk – 1000-year event)



4.2.5 The variation between the modelled flood extents for Grimescar Dike and the surface water mapping is likely due to the inclusion of detail such as channel cross sections, structure conveyance and also landforms representative of the present day.

5.0 Summary and Conclusions

5.1 Introduction

5.1.1 This report presents a Hydraulic Modelling Exercise for a 1D2D ESTRY-TUFLOW model for Grimescar Dike based on 1m DTM LiDAR Data, topographical survey and detailed channel and structure survey in order to define baseline flood extents for the development Site.

5.1.2 The Site is shown to lie in Flood Zone 1 but is shown to be at risk from surface water flooding, which is likely associated with Grimescar Dike and as such, is fluvial in nature.

5.1.3 The model was run for a range of return periods to establish the baseline fluvial flood extents and parameters, including blockage assessments for key in-channel structures. Sensitivity analysis was carried out to understand the seasonal effects of vegetation and impact of downstream boundary levels upon model results within the Site. An up-to-date climate change allowance of +31% and +51% representing the Aire and Calder Management Catchment Higher Central and Upper End Estimate) has also been applied to the 1 in 100-year event.

5.1.4 A hydrological assessment, inclusive of a desk-based assessment of catchment descriptors, was undertaken, which considered recognised methodologies such as FEH Statistical and ReFH2, to provide hydrological inputs, in the form of hydrographs for use in the hydraulic model. The hydrological assessment determined that peak flows and hydrographs from the FEH Statistical method were most appropriate for the contributing catchment.

5.2 Existing Flood Risk

5.2.1 A 1D2D ESTRY-TUFLOW model has been constructed using detailed channel and structure survey and up to date input hydrology for Grimescar Dike.

5.2.2 The baseline model was run for a range of return periods to establish the baseline fluvial flood extents and parameters. Up-to-date climate change allowances of +31% and +51% (representing the Aire and Calder Management Catchment (2070 – 2115) have also been applied to the 1 in 100-year event following Environment Agency guidance.

5.2.3 The results from the modelling exercise shows that flood extents within the Site are reduced when compared to Environment Agency surface water mapping.

5.2.4 The reduction in flood extent is due to the inclusion of detailed channel and structure survey as well as LIDAR and topographical representative of present-day landforms.

5.2.5 The baseline modelling demonstrated that:

- The water does not exit the channel for any modelled event within the Site boundary, except for a small area at the western extent of the Site, associated with the 100-year+51%CC, and the 1000-year events. There are no additional overland flow pathways at any point in the model extent. There is an increase in flooding upstream of Culvert 1 but does not exceed the banks of the watercourse.
- Sensitivity analysis shows that flood extents within the Site are not sensitive to manning's roughness changes. Increased and decreased roughness causes an average of +/-0.03m difference to the water levels within the Site itself.
- Consideration of the surface water flow pathway, shown to enter Grimescar Dike downstream of Culvert 2, through a 50% input peak flow split, showed some limited

sensitivity within a small area located in the western Site extent. The remainder of the Site shoed negligible sensitivity.

5.2.6 A comparison of Environment Agency 100-year surface water mapping (medium risk) and modelled 1 in 100-year flood extent for Grimescar Dike shows that flood extents are largely reduced across the Site and entire model extent. This likely due to the Grimescar Dike channel being underrepresented in the coarse grid used in the surface water mapping and omission of detailed cross sections and structures within the model.

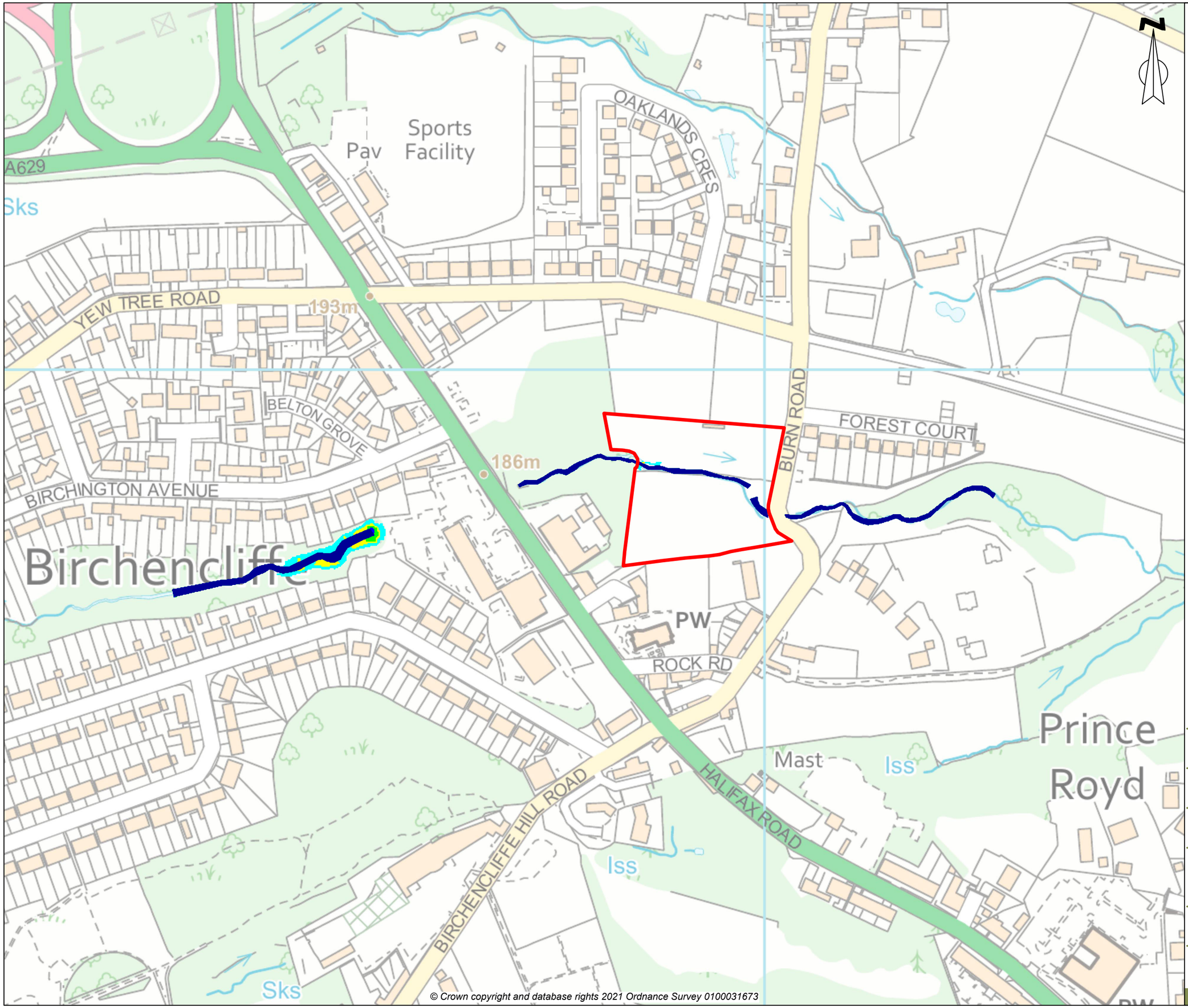
5.2.7 A comparison of Environment Agency 1000-year surface water mapping (low risk) and modelled 1 in 1000-year flood extent for Grimescar Dike shows that flood extents are reduced across the Site and model domain.

5.2.8 The variation between the modelled flood extents for Grimescar Dike and the surface water mapping is likely due to the inclusion of detail such as channel cross sections and structure conveyance.

5.3 Conclusion

5.3.1 The 1D2D ESTRY-TUFLOW hydraulic modelling has utilised detailed channel survey and up to date hydrological inputs. The exercise has demonstrated the existing/baseline fluvial flood outlines within the Site. The modelling has demonstrated a reduction in fluvial flooding extent associated with Grimescar Dike, when compared to Environment Agency surface water mapping. Similarly, the modelling reflects the existing extents as shown on the Environment Agency Flood fluvial flood risk mapping, which supports the conclusion that the proposed development is not at risk of flooding.

DRAWINGS



Key

- Site Boundary
- 20yr
- 100yr
- 1000yr
- 100yr+31%CC
- 100yr+51%CC

enzygo
environmental consultants
Samuel House, 5 Fox Valley Way, Stocksbridge, Sheffield, S36 2AA

CLIENT:
Wiggett Construction Group Limited

SCALE: 1:2,500@A3

PROJECT REF: SHF.1935.001

DRAWN: HDR

CHECKED: RH

DATE: Oct 2021

PROJECT:
Burn Road, Huddersfield
Hydraulic Modelling

TITLE:
Baseline Flood Outline Drawing

FIGURE NO:
SHF.1935.001.HY.D.001.A

APPENDICES

Appendix 1 – Hydrological Assessment

enzygo
environmental consultants



Hydrological Assessment

Burn Road, Huddersfield

Wiggett Construction Group Ltd

SHF.1935.001.HY.R.001.A

'Experience and expertise working in union'

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Watercourse at Burn Road, Huddersfield

Project:	SHF.1935.001.HY.R.001.A - Hydrological Assessment
For:	Wiggett Construction Group Ltd
Status:	Draft for Client Comment
Date:	November 2021
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Appendix 1 - ReFH2 Calculation Logs

1.0 Introduction

1.1 Background

1.1.1 Enzygo Ltd were commissioned by Wiggett Construction Group Ltd to undertake Hydrological Calculations to inform a hydraulic model of a river at Burn Road, Huddersfield in support of a residential development.

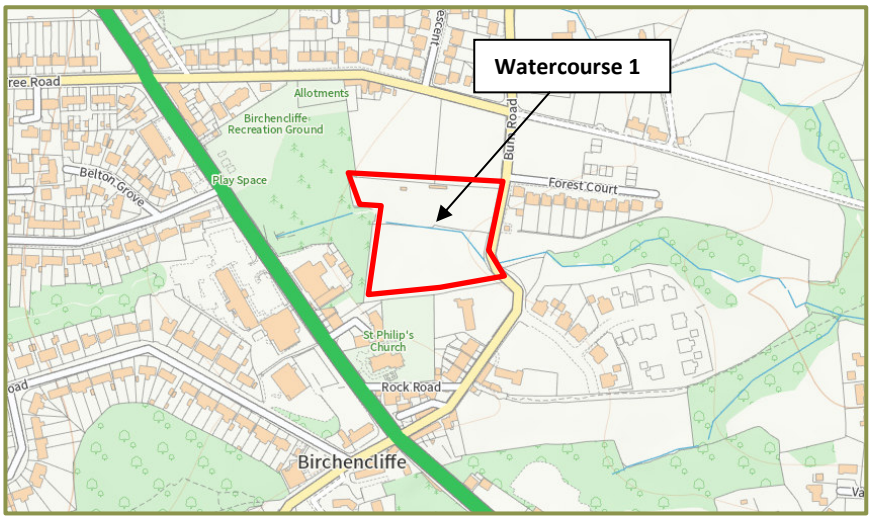
1.1.2 The Site is centred on National Grid Reference (NGR) 411957, 418926.

1.1.3 The watercourse (Hereafter 'Watercourse 1') is an 'ordinary watercourse' and conveys flows east through the centre of the development Site. Watercourse 1 becomes Grimescar Dyke (a 'main river') approximately 275m downstream of the site. Grimescar Dyke is a tributary to the River Colne, which is approximately 10km downstream of the site, at NGR 415222, 417584. Watercourse 1 is within the 'Humber' River Basin District and 'Aire and Calder' Management catchment.

1.1.4 Environment Agency Flood Map for Planning mapping, included as Figure 1.1, shows that the Site is within Flood Zone 1 (Low Risk). A Flood Risk Assessment (FRA) undertaken by a 3rd party for the site concludes that the Site is, therefore, at negligible risk of fluvial flooding. However, Kirklees Council have requested demonstration of flood risk due to the presence of Watercourse 1 within the Site.

1.1.5 At the request of Kirklees Council Flood Management and Drainage, Enzygo Ltd have been commissioned by Wiggett Construction Group Ltd to undertake a hydraulic modelling exercise to produce fluvial flood extents and parameters for Watercourse 1, within, and in the vicinity of the Site. This requires up to date peak flow hydrological estimates.

Figure 1.1: Environment Agency Flood Map for Planning Mapping



Red: Site Boundary

1.2 Purpose of the Report

1.2.1 The purpose of this report (SHF.1935.001.HY.R.001.A, October 2021) details the methodology and results of a hydrological assessment, which informs the peak flow inputs to the Hydraulic model to provide an updated flood extent for the proposed development Site. This

Hydrological Assessment report is included as Appendix 1 of the Hydraulic Modelling report (SHF.1935.001.HY.R.002.A, October 2021)

2.0 Hydrological Assessment

2.1 Catchment Hydrology

River Basin District

2.1.1 Watercourse 1 resides within the Humber River Basin District (RBD) and Aire and Calder Management catchment. The climate change allowances within the Aire and Calder Management Catchment are +31% (Higher Central) and +51% (Upper End estimate) for the Total Potential Change anticipated for the 2080's (2070 to 2115)[1].

Catchment Boundary

2.1.2 The FEH Webservice catchment boundary at the model downstream boundary (NGR 412250, 418880) is shown in Figure 2.1 and encompasses an area of 0.62 km^2.

2.1.3 The FEH Webservice catchment boundary (Figure 2.1) has been checked against LIDAR data, and OS mapping. The FEH Webservice boundary was adjusted to a boundary that more accurately follows the LiDAR contours (hereafter 'adjusted boundary'). This adjusted catchment remains at 0.58 km^2. The adjusted boundary is presented in Figure 2.1.

2.1.4 As shown in Figure 2.1, the adjustments to the FEH webservice catchment do not significantly change the shape of the catchment. As such, drainage path lengths and slopes will remain representative.

Figure 2.1: Catchment Boundaries and 2M DTM LIDAR data



***Green**: FEH Webservice Catchment. **Black**: Adjusted Catchment*

1 https://environment.maps.arcgis.com/apps/webappviewer/index.html?id=363522b846b842a4a905829a8d8b3d0c

Catchment Descriptors

2.1.5 Analysis of the FEH Webservice Catchment Descriptors (Table 2.1) for the 0.58 km^2 adjusted catchment was undertaken.

2.1.6 A discussion of the Catchment Descriptors downloaded from the FEH Webservice (Table 2.1), and how key Catchment Descriptors have been checked through a desktop study is provided below.

Table 2.1: Catchment Descriptors from the FEH Webservice Catchment

Catchment Descriptor	Value	Catchment Descriptor	Value
AREA	0.62 (0.58)	SPRHOST	4.45 (33)
ALTBAR	228	URBCONC1990	0.84
ASPBAR	91	URBEXT1990	0.1526
ASPVAR	0.64	URBLOC1990	0.6860
BFIHOST	0.835 (0.53)	URBCONC2000	0.8060
BFIHOST19	0.843 (0.53)	URBEXT2000	0.1687
DPLBAR	1.03	URBLOC2000	0.6940
DPSBAR	80.9	C	-0.025
FARL	1	D1	0.381
FPEXT	0.0040	D2	0.402
FPDBAR	0.020	D3	0.322
FPLOC		E	0.305
LDP	1.99	F	2.56
PROPWET	0.57	C(1 km)	-0.025
RMED-1H	10.9	D1(1 km)	0.026
RMED-1D	39.9	D2(1 km)	0.373
RMED-2D	52.6	D3(1 km)	0.413
SAAR	1025	E(1 km)	0.306
SAAR4170	1000	F(1 km)	2.436

Adjusted values are shown in brackets.

BFIHOST

2.1.7 BFIHOST is the baseflow index developed using the Hydrology of Soil Types (HOST) classification and is the baseflow proportion of the flow on average. It is estimated based on daily mean flow data. Baseflow comprises water entering the watercourse through shallow subsurface flow and groundwater flow (mechanisms other than direct surface runoff); hence permeable soils and geology tend to yield a higher baseflow.

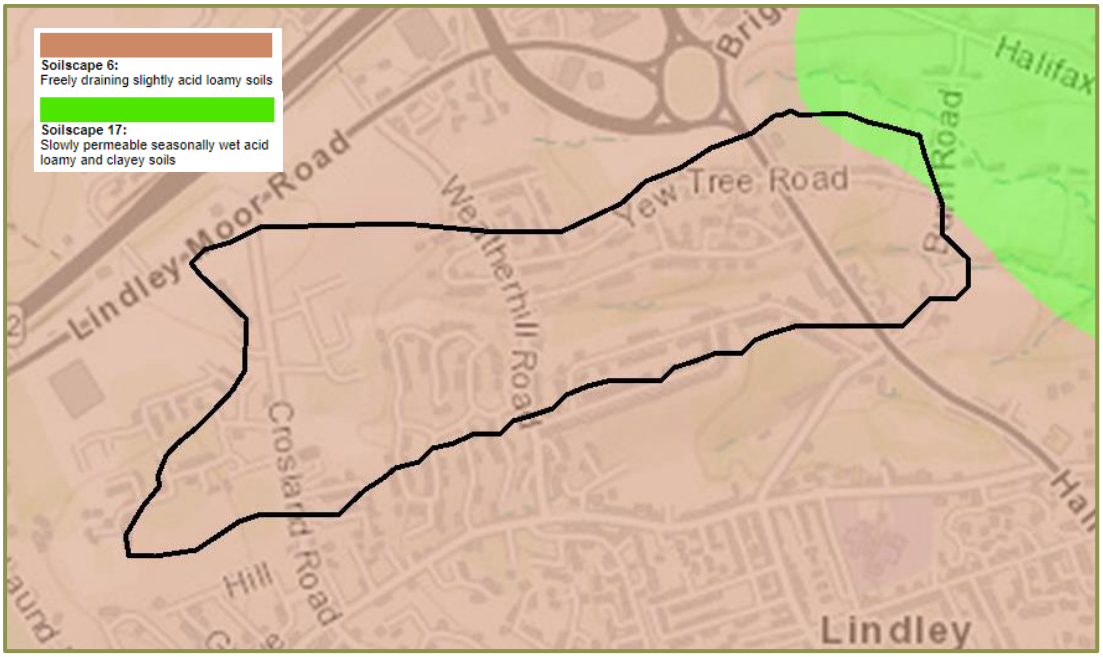
2.1.8 A new catchment descriptor called BFIHOST19 is now available in FEH Webservice datasets. BFIHOST19 addresses a number of issues associated with the original BFIHOST descriptor[2]

2.1.9 BFIHOST19 includes revised regression methods used to estimate BFIHOST and also has improved classification of rare soil types.

2.1.10 The National Soils Resources Institute (Cranfield University) HOST mapping (Figure 2.2) was reviewed to verify the BFIHOST and BFIHOST19 value.

[2] https://fehweb.ceh.ac.uk/News/Article/bfihost19nowavailable

Figure 2.2: Soils Mapping



Soils Data © Cranfield University (NSRI) and for the Controller of HMSO [2021].

2.1.11 The National Soils Resources Institute (Cranfield University) Soilscapes map (Figure 2.2) shows two soil types within the adjusted catchment:

- Soilscape 6 (HOST 8 - Free draining permeable soils in unconsolidated loams or clays with groundwater at less than 2m from the surface.): 0.57 km^2 (BFIHOST of 0.56)
- Soilscape 17 (HOST 23 - Slowly permeable soils with slight seasonal waterlogging and low storage capacity over impermeable clay substrates with no storage capacity) 0.011 km^2 (BFIHOST of 0.22)

2.1.12 Based on the soil types identified in the adjusted catchment, and associated areas, a weighted area calculation has been undertaken to verify the FEH webservice BFIHOST value.

- (0.56*0.57) + (0.22*0.011)/0.5811 = 0.55

2.1.13 The weighted BFIHOST value of 0.55 represents a significant decrease when compared to the FEH Webservice value of 0.84 (BFIHOST) for the watercourse.

2.1.14 As the above variation is significant, the original FEH webservice values have been adjusted.

2.1.15 Within the western area of the Watercourse 1 catchment, there has been significant residential development. The development supporting documents include various geological investigations and soakaway tests. The geological investigations largely support the geological mapping (Figure 2.2) and also show that infiltration-based SuDS is not feasible. A BFIHOST of 0.84 and SPRHOST of 4.45 implies significant permeability with very little rainfall occurring as runoff. This is not supported by the soakaway test results. As such, the works undertaken to support the development(s) confirms that an adjustment of BFIHOST (and SPRHOST) is appropriate and representative.

SPRHOST

2.1.16 The SPRHOST parameter reflects the amount of surface runoff in a catchment and is also based on the HOST soils classifications.

2.1.17 SPRHOST was verified by a review of the HOST mapping (Figure 2.2) and weighted average calculation.

2.1.18 The National Soils Resources Institute (Cranfield University) Hydrology of HOST soils mapping (Figure 2.2) shows two soil types within the catchment;

- Soilscape 6 (HOST 8 - Free draining permeable soils in unconsolidated loams or clays with groundwater at less than 2m from the surface.): 0.57 km^2 (SPRHOST of 30)
- Soilscape 17 (HOST 23 - Slowly permeable soils with slight seasonal waterlogging and low storage capacity over impermeable clay substrates with no storage capacity) 0.011 km^2 (SPRHOST of 60)

2.1.19 Based on the soil types identified in the adjusted catchment, and associated areas, a weighted area calculation has been undertaken to verify the FEH webservice SPRHOST value.

- (30*0.57) + (60*0.011) /0.5811 = 30.4

2.1.20 Based on the findings of the geological investigations within the Watercourse 1 catchment and reduction on BFIHOST, the adjusted SPRHOST value has been caried forward.

PROPWET

2.1.21 PROPWET describes the proportion of time that soils are wet. PROPWET values for the UK range from approximately 0.80 in Northern Scotland where there is high annual rainfall, to 0.20 in East Anglia where annual rainfall is much lower.

2.1.22 Low PROPWET values tend to inhibit flooding, as the catchment is not saturated prior to a flood event and there is higher capacity for infiltration, the opposite is true for catchments with higher PROPWET values. The PROPWET value of 0.57 is moderate and may be explained by the following factors:

- Wet spells only occur at a low frequency and tend to be of a relatively short duration (supported by the SAAR figures below).
- The adjusted catchment is in the south Pennines of northern England where rainfall levels are higher compared to the south and east of England. As stated above, moderate to high PROPWET values are representative of saturated catchments with low to moderate capacity for infiltration. The BFIHOST values, representing permeable soils over impermeable bedrock, support the moderate PROPWET value.

2.1.23 The PROPWET values taken from the FEH Webservice (0.57) is considered representative of the adjusted catchment.

FARL

2.1.24 The FARL value is a measure of flow attenuation caused by reservoirs and lakes, and ranges from 0 (total attenuation) to 1.0 (no discernible attenuation). The FARL value of 1 indicates that there is no attenuation due to reservoirs or lakes. Scrutiny of OS mapping and aerial photography did not identify any lakes, ponds, or reservoirs within the Watercourse 1 catchment.

2.1.25 The FARL value of 1 for the watercourse taken from the FEH Webservice data is therefore considered representative of the adjusted catchments.

URBEXT

2.1.26 The Urban Extent URBEXT1990 output of 0.1526 for Watercourse 1 indicates a 'Heavily Urbanised' catchment. The FEH catchment descriptor URBEXT2000 was calculated to be 0.1687 which also indicates a 'Heavily Urbanised' catchment. The URBEXT2000 value relates to the eastern catchment (to the east of Weatherhill Road) with the western catchment being rural with no urbanisation (Figure 2.3).

2.1.27 Between the year 2000 and 2021, there has been significant residential development upstream of the site within the upstream (western) extent of the catchment to the west of Weatherhill road.

2.1.28 Scrutiny of google earth historical imagery and the Kirklees Council planning portal, the increased urbanisation all occurred between the years of 2016 and 2021 and were subject to the implementation of SuDS drainage strategies.

Figure 2.3: Urban Extents



***Top**: 2002 **Bottom**: 2021*

2.1.29 Although urban extent has increased between the years of 2016 and 2021, runoff has been restricted to either greenfield runoff rates or greenfield Qbar through SuDS schemes and use of attenuation basins. As such, the impermeable surfaces associated with the increased urban extent will not contribute to increased flood flows within the Grimescar Beck catchment.

2.1.30 Based on the above, the URBEXT2000 value will remain unadjusted to account for the implementation of SuDS within the new areas of development. The URBEXT2000 value relates to the urbanised areas to the east of Weatherhill Road that was present prior to the year 2000 and does not benefit from SuDS drainage.

SAAR

2.1.31 SAAR values within the FEH represent standard average annual rainfall data for the standard period 1961-1990.

2.1.32 The catchment is in northern England where rainfall levels are generally higher than the south of the UK. Catchments in the north of England are wetter for a greater proportion of the time reflecting the increase in reliable frontal rainfall and lower evapotranspiration rates.

2.1.33 A SAAR value of 1025mm for the watercourse indicates a moderately wet catchment. Given the catchments location within the north of England and at a relatively high altitude, the SAAR values taken from the FEH Webservice is considered representative and will be carried forward in this assessment.

DPSBAR

2.1.34 The Drainage Path Slope (DPSBAR) shows a value of 80.9, which is indicative of a steeply sloping catchment. This is supported by a review of OS mapping and LiDAR. The DPSBAR value taken from the FEH Webservice is considered representative of the adjusted catchment due to only minor changes to the area with negligible change to the catchment shape.

2.1.35 The FEH Webservice DPSBAR value of 80.9 is considered representative and has not been adjusted.

2.2 FEH Statistical Method (Adjusted Catchment)

Introduction

2.2.1 In order to determine the most appropriate hydrological methodology for the adjusted catchment, the peak flood flows from FEH Statistical and ReFH2 methodologies were assessed for the Adjusted Catchment, inclusive of adjustments to BFIHOST, SPRHOST and AREA.

2.2.2 Following the FEH Statistical and ReFH2 assessments, justification will be provided for the carry forward method to be utilised for peak flow assessments for the catchment.

2.2.3 The FEH Statistical Method is based on an Index Flood, which is the median annual maximum flood from Catchment Descriptors and then improving this using data from an appropriate Gauging Station (if available). This reduces the error associated with the estimation of QMED using only Catchment Descriptors. QMED is formally defined as the middle-ranking value in the series of annual maximum floods, where the annual maximum series comprise the largest flow observed in each year. QMED is the flood that is exceeded on average “every other year” and can therefore loosely be attributed a return period of 1 in 2-years.

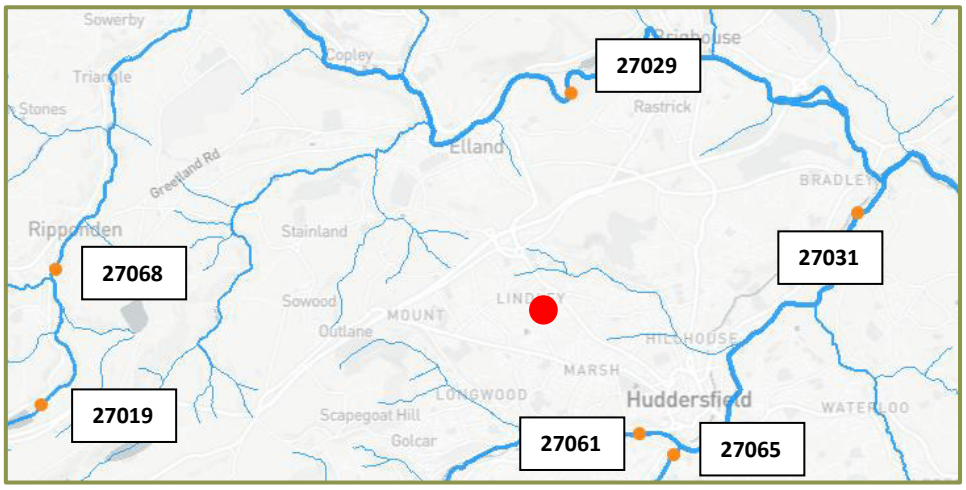
QMED Estimation

2.2.4 There are no gauging stations within the Watercourse 1 or Grimescar catchments, and no gauging stations in the vicinity of the site.

2.2.5 The closest gauging stations to the Site are presented in Figure 2.3. Of the gauging stations presented in Figure 2.3, 27029, 27031, 27061, 27065 and 27068 have contributing catchments greater the 50 times the watercourse 1 catchment. As such, these stations are not considered suitable as donor stations for the Watercourse 1 catchment.

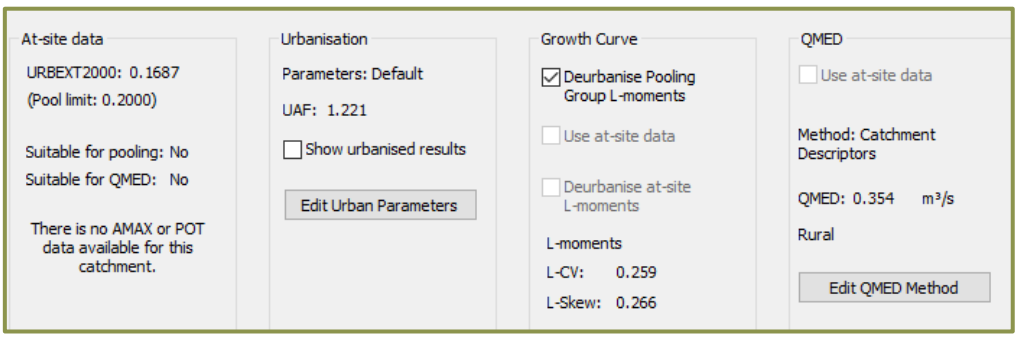
2.2.6 Station 27019 located approximately to the south-west of the Site has a catchment area 16km^2. However, station 27019 is not listed as suitable for QMED or pooling and is located downstream of Booth Wood Reservoir. As such, station 27019 is not considered a suitable donor station.

Figure 2.3: Map of Gauging Stations



2.2.4 QMED$_{CDS}$ for the adjusted catchment, from catchment descriptors alone is 354m^3/s (Figure 2.4).

Figure 2.4: QMED Derivation



2.2.5 A Catchment descriptors QMED value of 354m^3/s will be carried forward throughout the FEH Statistical assessment.

Pooling Group Analysis

2.2.6 The pooling group analysis and QMED estimation (based on Catchment Descriptors) is described below. WINFAP FEH v5 software and the NRFA (National River Flow Archive) Peak Flow v10 dataset was used the undertake the assessment.

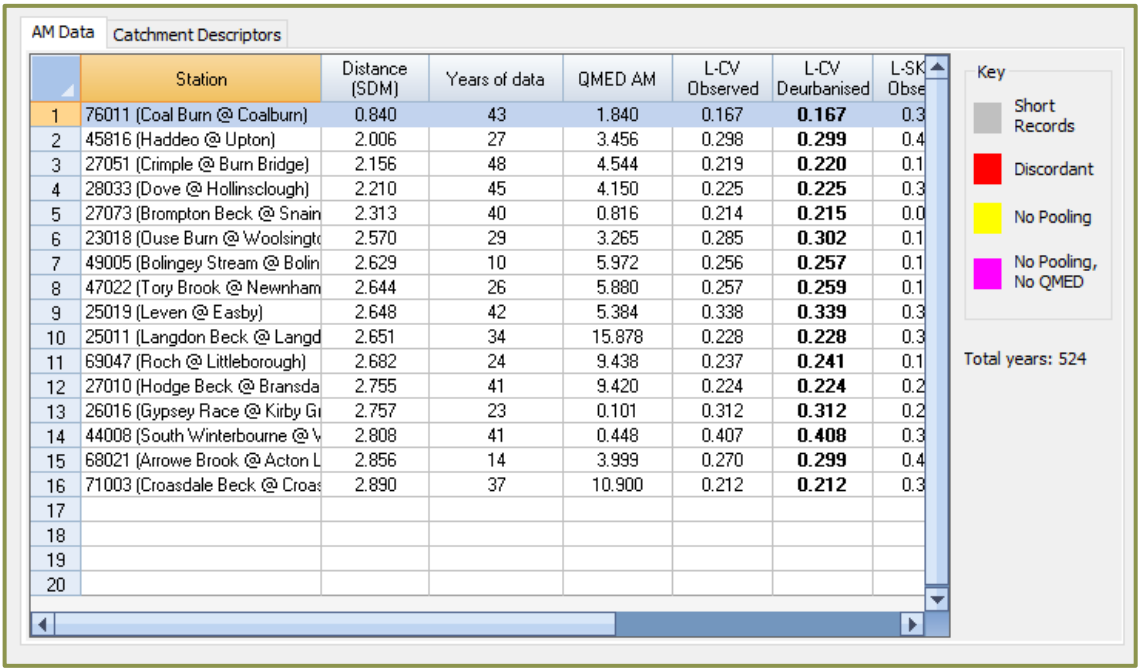
2.2.7 To estimate the magnitude of the statistical flood events occurring within the ungauged (adjusted) catchment, it is necessary to determine a flood growth curve and a flood frequency curve. This is done by forming a pooling group, which is a group of hydrologically similar catchments across the UK which have gauged records covering a statistically adequate number of years to obtain reliable flood estimates and subjecting this group to statistical analysis.

2.2.8 To calculate reliable flood estimates, the FEH recommends that a pooling group should contain five times as many station-years as the target return period (5T) however, the 'Improved Statistical Method' (2008) recommends that a fixed pooling group size of at least 500 annual maxima events should be used for all return period events. This revised advice has been adopted in this instance.

2.2.9 The FEH Webservice Catchment Descriptors in Table 2.2 were imported into WINFAP-FEH v4 and an initial pooling group with 505 years of data was created (Figure 2.5).

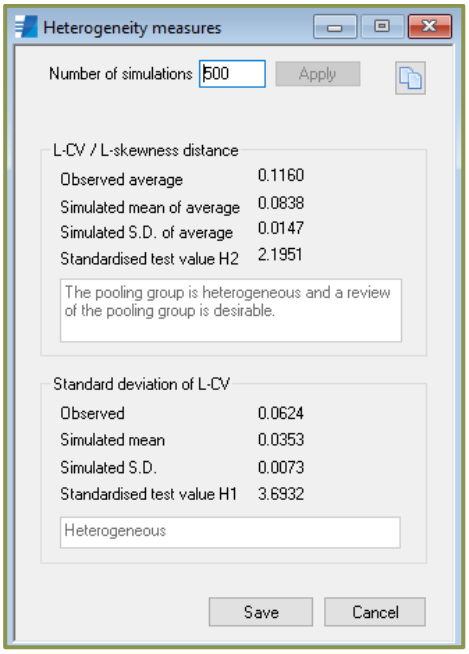
2.2.10 The initial pooling groups were identified as 'heterogenous' and a review of the pooling group is 'desirable' (Figure 2.6).

Figure 2.5: Initial Pooling Group



	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SK Obse
1	76011 (Coal Burn @ Coalburn)	0.840	43	1.840	0.167	**0.167**	0.3
2	45816 (Haddeo @ Upton)	2.006	27	3.456	0.298	**0.299**	0.4
3	27051 (Crimple @ Burn Bridge)	2.156	48	4.544	0.219	**0.220**	0.1
4	28033 (Dove @ Hollinsclough)	2.210	45	4.150	0.225	**0.225**	0.3
5	27073 (Brompton Beck @ Snain	2.313	40	0.816	0.214	**0.215**	0.0
6	23018 (Ouse Burn @ Woolsingto	2.570	29	3.265	0.285	**0.302**	0.1
7	49005 (Bolingey Stream @ Bolin	2.629	10	5.972	0.256	**0.257**	0.1
8	47022 (Tory Brook @ Newnham	2.644	26	5.880	0.257	**0.259**	0.1
9	25019 (Leven @ Easby)	2.648	42	5.384	0.338	**0.339**	0.3
10	25011 (Langdon Beck @ Langd	2.651	34	15.878	0.228	**0.228**	0.3
11	69047 (Roch @ Littleborough)	2.682	24	9.438	0.237	**0.241**	0.1
12	27010 (Hodge Beck @ Bransda	2.755	41	9.420	0.224	**0.224**	0.2
13	26016 (Gypsey Race @ Kirby Gi	2.757	23	0.101	0.312	**0.312**	0.2
14	44008 (South Winterbourne @ V	2.808	41	0.448	0.407	**0.408**	0.3
15	68021 (Arrowe Brook @ Acton L	2.856	14	3.999	0.270	**0.299**	0.4
16	71003 (Croasdale Beck @ Croas	2.890	37	10.900	0.212	**0.212**	0.3
17							
18							
19							
20							

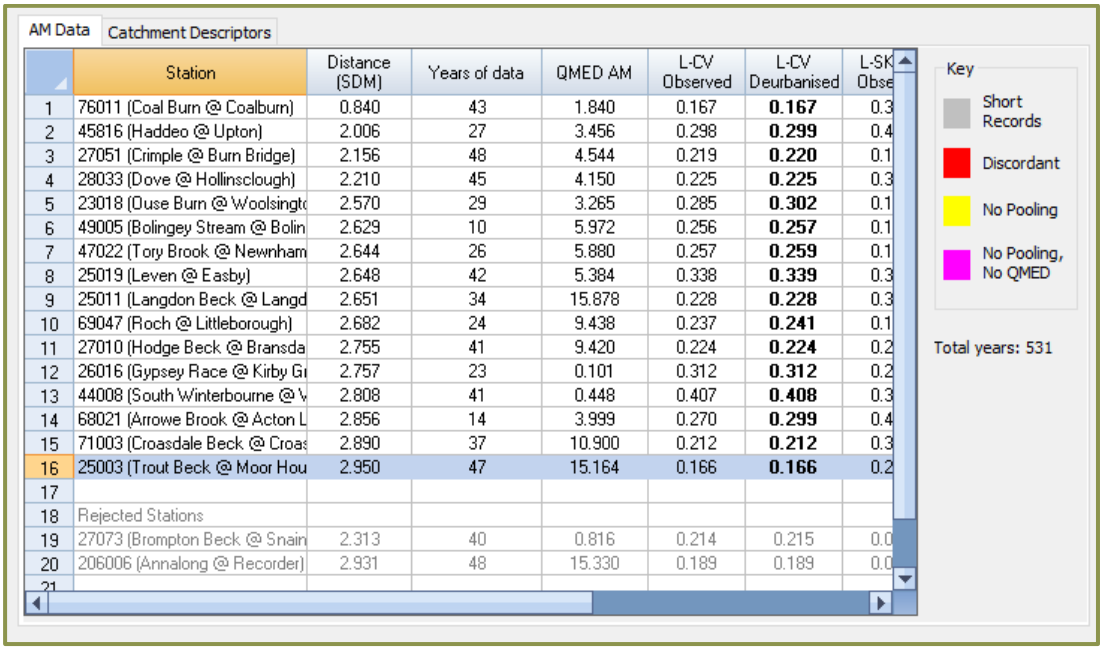
Figure 2.6: Heterogeneity Measure (Initial Pooling Group)



2.2.11 A review of the pooling group was undertaken starting with the stations with the highest discordancy. Station flow data, gauging method/type, catchment descriptions and photos provided on the NRFA website were assessed for each station. The review for the catchment is summarised below:

- **27073: Brompton Beck @ Snainton Ings**: High BFIHOST. **Action – Remove**
- **206006: Annalong @ Recorder:** Increase pooling group years to >500.
- **206006: Annalong @ Recorder:** Decommissioned in 1943, absence of data relating gaugings or containment of flows. Very flat, almost negative growth curve. **Action – Remove**
- **25003: Trout Beck @ Moor House:** Increase pooling group years to >500.
- **44008: South Winterbourne @Winterbourne Steepleton:** High BFIHOST. **Action – Remove**
- **106002: Laxdale @ Laxdale:** Increase pooling group years to >500.
- **106002: Laxdale @ Laxdale:** FARL of 0.88 indicating significant influence by Numerous Lochs within the catchment. **Action – Remove**
- **27032: Hebden Beck @ Hebden**: Increase pooling group years to >500.

Figure 2.7: Reviewed Pooling Group



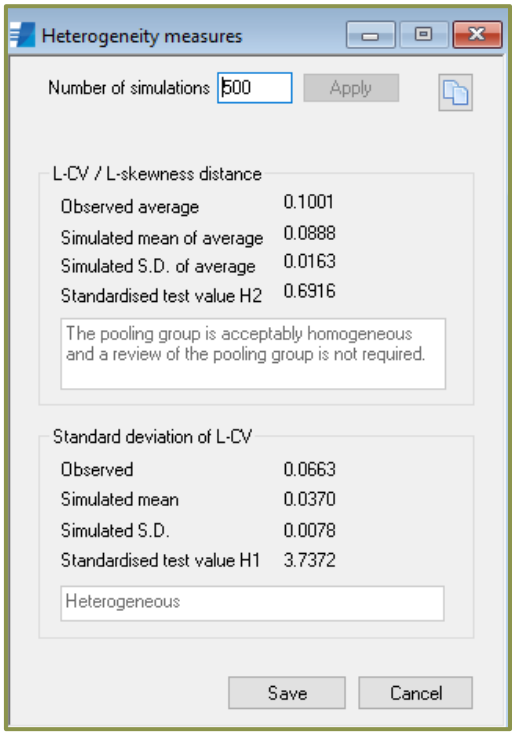
AM Data | Catchment Descriptors

	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SK Obse
1	76011 (Coal Burn @ Coalburn)	0.840	43	1.840	0.167	**0.167**	0.3
2	45816 (Haddeo @ Upton)	2.006	27	3.456	0.298	**0.299**	0.4
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7	47022 (Tory Brook @ Newnham	2.644	26	5.880	0.257	**0.259**	0.1
8	25019 (Leven @ Easby)	2.648	42	5.384	0.338	**0.339**	0.3
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14	68021 (Arrowe Brook @ Acton L	2.856	14	3.999	0.270	**0.299**	0.4
15	71003 (Croasdale Beck @ Croas	2.890	37	10.900	0.212	**0.212**	0.3
16	25003 (Trout Beck @ Moor Hou	2.950	47	15.164	0.166	**0.166**	0.2
17							
18	Rejected Stations						
19	27073 (Brompton Beck @ Snain	2.313	40	0.816	0.214	0.215	0.0
20	206006 (Annalong @ Recorder)	2.931	48	15.330	0.189	0.189	0.0
21							

Key
- Short Records
- Discordant
- No Pooling
- No Pooling, No QMED

Total years: 531

Figure 2.8: Heterogeneity Measure (Reviewed Pooling Group)



2.2.12 Following the review, the pooling group (Figure 2.7) is 'acceptably homogenous' and a review of the pooling group is 'not required' (Figure 2.8). As such, the reviewed pooling group was carried forward with no further review.

2.2.13 The growth curve fittings and flood frequency curve fittings have been derived for the Adjusted Catchment and $QMED_{CDS}$ (0.354m^3/s) derived from the catchment descriptors

pooling group with an Urban Adjustment Factor (UAF) (1.221) applied. Urbanised QMED is 0.432m^3/s.

2.2.14 Generalised Logistic (GL), Generalised Extreme Value (GEV), Pearson Type III (PTIII), and Generalised Pareto (GP) fittings were used to determine goodness of fit.

2.2.15 GL gave the best fit for Watercourse 1. The results can vary slightly, depending on the chosen distribution for the statistical analysis. The Pooling Group growth curve fittings and flood frequency curve fittings are included below in Table 2.2.

Table 2.2: Pooled Group Growth Fittings and Flood Frequency

Return period	Growth Fittings (GL)	Peak Flow (m^3/s)
2	1.000	0.432
5	1.364	0.589
10	1.662	0.717
20	2.010	0.868
50	2.587	1.117
100	3.138	1.355
200	3.818	1.649
1000	6.085	2.627

2.3 ReFH2 Method

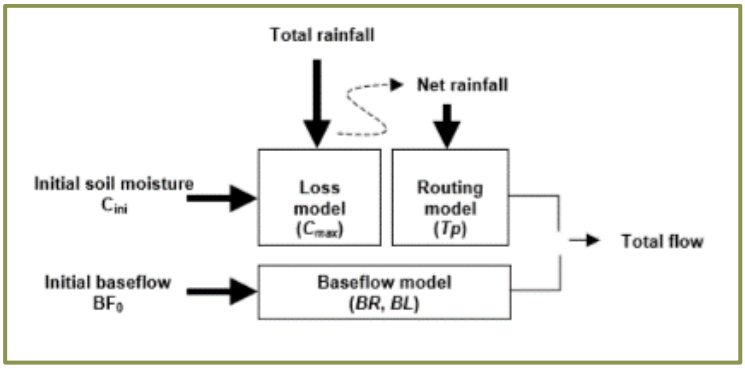
Introduction

2.3.1 The Revitalised Rainfall-runoff (ReFH) model was first published in 2005 as an update to the previous FEH rainfall-runoff method, the FSR/FEH rainfall-runoff method. ReFH was based on robust hydrological modelling techniques and was an improvement over the FEH/FSR Rainfall Runoff method (FEH), as described in the FEH. The method uses Catchment Descriptors from the FEH Webservice, to generate design flood events of specific return periods.

2.3.2 ReFH2 was released in early 2015, with a significant update (Version 2.1), published in November 2015. ReFH2 includes an extension of the ReFH model to represent urban catchments and is compatible with FEH2013 rainfall frequency statistics.

2.3.3 The ReFH model has three components: a loss model (Cmax), a routing model (Tp) and a base flow model (BR, BL) (Table 2.4). The loss model uses a soil moisture accounting approach to define the amount of rainfall occurring over the catchment that is converted to direct runoff. The rainfall losses are derived as the event unfolds, rather than being defined by a fixed value of percentage runoff. The routing component of ReFH uses the unit hydrograph concept, adopting a 'kinked' triangle as the standard shape. Finally, the base flow model is based on the linear reservoir concept with its characteristic recession defined by an exponential decay controlled by the recession constant termed base flow lag (Figure 2.9).

Figure 2.9: Schematic Representation of the ReFH Model



Source: Wallingford HydroSolutions Ltd 2016. The Revitalised Flood Hydrograph Model ReFH2.2: Technical Guidance.

Table 2.3: Summary of the Six ReFH Model Parameters

Name	Parameter or Initial Condition	Description
T_p	Model parameter	Unit hydrograph time to peak (hours)
B_L	Model parameter	Baseflow recession constant or lag (hours)
B_R	Model parameter	Baseflow recharge
C_{Max}	Model parameter	Maximum soil moisture capacity (mm)
C_{ini}	Initial condition	Initial moisture content (mm)
BF_0	Initial condition	Initial baseflow (m^3s^{-1})

Source: Wallingford HydroSolutions Ltd 2016. The Revitalised Flood Hydrograph Model ReFH2.2: Technical Guidance.

2.3.4 The ReFH2 calculations were undertaken within the ReFH2 standalone software to calculate peak flow estimates from Catchment Descriptors as provided in Table 2.1.

Storm Duration Estimation

2.3.5 The default rainfall parameters derived by ReFH2 from the FEH 2013 rainfall model were applied. A storm duration of 2.10 hours and a timestep of 0.10 hours were used. A Seasonal Correction Factor (SCF) of 0.77 and Areal Reduction Factor (ARF) of 0.98 were also applied. Calculation extracts for the 1 in 1000-year event is included in Appendix 1.

Peak Flow Estimation

2.3.6 In line with ReFH2 Method guidance, a winter seasonality (default storm profile) was selected and flows were estimated for each required return period. Wallingford Hydrosolutions guidance[3] states that:

- Summer storms are selected by default if:
  - URBEXT2000 is ≥ 0.30, or
  - 0.15 ≤ URBEXT2000 < 0.30 and BFIHOST19 is ≥ 0.65.

[3] https://www.hydrosolutions.co.uk/knowledge-base/seasonality-i-use-summer-winter/

- Winter storms are selected by default in all other case

2.3.7 The model parameters for the ReFH2 method should ideally be based on actual flood event data comprising rainfall and flow records rather than Catchment Descriptors alone. However, due to the lack of available flow data for the catchment, the ReFH2 design standards have been adopted in this instance based on the technical guidance. The key ReFH2 model parameter values are provided in Table 2.5. The peak flows calculated using the ReFH2 Method are summarised in Table 2.6. Calculation extracts for the 1 in 1000-year event is included in Appendix 1.

Table 2.4: ReFH2 Parameters

Parameter	Unit	Default Value	Adjusted Value
T_p	Hours (hrs)	2.06	-
B_L	Hours (hrs)	27.5	-
B_R	-	2.48	-
C_{Max}	Millimetres (mm)	396	-
C_{ini}	Millimetres (mm)	82.75	-
BF_0	m^3/s	0.02	-

Table 2.5: ReFH2 Method Peak Flows (Winter Profile)

Return Period	Peak Flow (m^3/s)
2	0.304
5	0.457
10	0.574
30	0.698
50	0.874
100	1.023
200	1.211
1000	1.784

Summary of Results

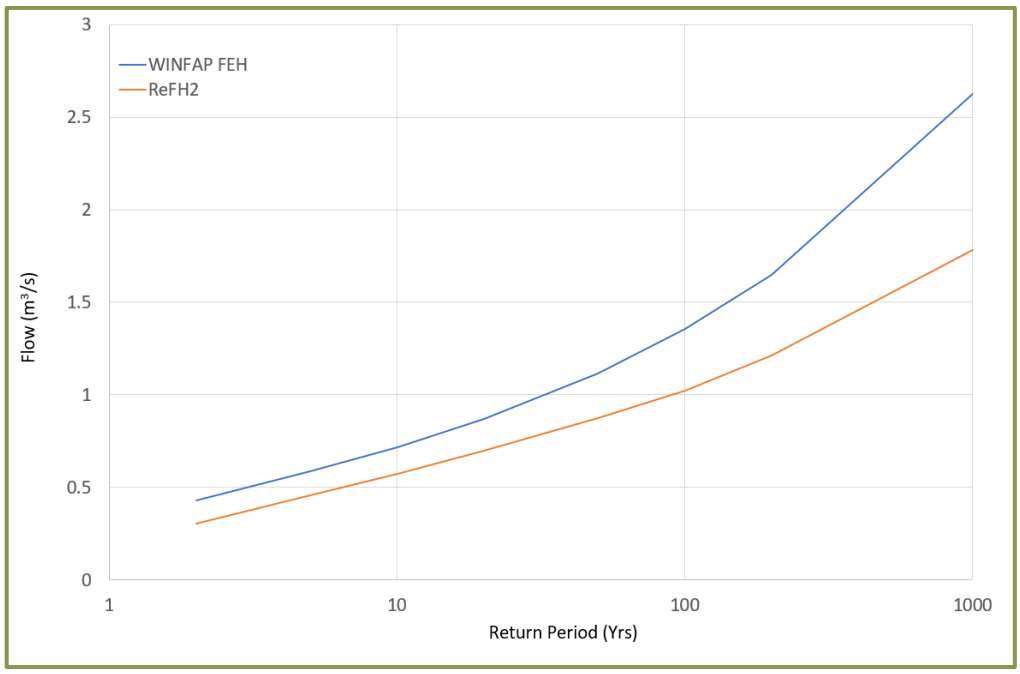
2.3.8 Table 2.6 and Figure 2.9 summarise the findings of the two hydrological methodologies.

Table 2.6: ReFH2 Method Peak Flows (Winter Profile)

Return Period	FEH Statistical method (Pooled Group Analysis - $QMED_{CDS}$)	ReFH2 Method (m^3/s)	Percentage Variation
2	0.432	0.304	42
5	0.589	0.457	29
10	0.717	0.574	25
20	0.868	0.698	24
50	1.117	0.874	28
100	1.355	1.023	32
200	1.649	1.211	36
1000	2.627	1.784	47
*100+31%CC	1.775	1.340	32
*100+51%CC	2.046	1.545	32

**Humber River Basin District (RBD) Aire and Calder Management Catchment are +31% (Higher Central) and +51% (Upper End estimate) for the Total Potential Change anticipated for the 2080's (2070 to 2115)[4].*

Figure 2.10: Graph Summary of Results



2.4 Analysis of Peak Flow and Choice Going Forward

Analysis of Peak Flow

2.4.1 It is expected that results using the different methods will vary. In urban catchments, the ReFH2 method normally gives larger estimates than the FEH Statistical (Pooled Group) method, which typically underestimates peak flows. However, in this urbanised catchment, FEH Statistical results in greater peak flows for all return periods (except the 1000-year estimate), based on catchment descriptors QMED. FEH statistical peak flows are between 24% and 47% greater than REFH2 for all return periods.

2.4.2 Below is a summary of the advantages and disadvantages associated with each of the methodologies.

FEH Statistical Method

2.4.3 Below is a summary of the advantages to using the Statistical Method within this study's catchments:

4 https://environment.maps.arcgis.com/apps/webappviewer/index.html?id=363522b846b842a4a905829a8d8b3d0c

- The method is based on a larger dataset than the ReFH2 method.
- Has undergone more direct calibration to reproduce flood frequency in the UK than the other methods.

2.4.4 Below is a summary of the disadvantages to using the Statistical Method within this study's catchments:

- The catchment is less than 1000km^2, therefore the Statistical Method has no advantage over the ReFH2 method.

ReFH2 Method

2.4.5 Below is a summary of the advantages to using the ReFH2 Method within this study catchment:

- The ReFH2 method is based on Catchment Descriptors specific to the study catchment, with Catchment Descriptors being verified or updated (i.e. AREA, and URBEXT updated to URBEXT2021).
- There are no continuous flow records as the Study Site is not directly gauged, and there are no gauges located within the vicinity of the Study Site.
- The return period is long, for example 1000 years.

Choice Going Forward

2.4.6 The assessment has shown that peak flows derived from Winfap FEH Statistical are up to 47% greater than those derived from FEH Statistical for Watercourse 1. Although the catchment is small and urbanised and ReFH2 uses catchment descriptors specific to the catchment, there is significant variation between the two methods. Due to the significance of the variation, and to adopt a precautionary approach, peak flows from the Winfap FEH Statistical method will be carried forward.

Appendix 1 – ReFH2 Calculation Logs

UK Design Flood Estimation

Generated on 27 September 2021 11:36:24 by Helena.duroe
Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details Checksum: 6183-A279

Site name: FEH_Catchment_Descriptors_412050_418900 (1)

Easting: 412050

Northing: 418900

Country: England, Wales or Northern Ireland

Catchment Area (km²): 0.62

Using plot scale calculations: No

Model: ReFH2.3

Site description: None

Model run: 1000 year

Summary of results

Rainfall - FEH 2013 model (mm):	103.89	Total runoff (ML):	17.79
Total Rainfall (mm):	78.90	Total flow (ML):	43.58
Peak Rainfall (mm):	4.08	Peak flow (m³/s):	1.88

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	05:06:00 [02:06:00]	Yes
Timestep (hh:mm:ss)	00:06:00	No
SCF (Seasonal correction factor)	0.77	No
ARF (Areal reduction factor)	0.98	No
Seasonality	Winter [Summer]	Yes

Loss model parameters

Name	Value	User-defined?
Cini (mm)	71.94	No
Cmax (mm)	500.3	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m^3/s)	0.02	No
BL (hr)	30.24	No
BR	2.92	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km^2)	0.4 [0.16]	Yes
Urbext 2000	0.41 [0.17]	Yes
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km^2)	0.00	Yes
Sewer capacity (m^3/s)	0.00	Yes

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
00:00:00	0.302	0.000	0.087	0.000	0.012	0.012
00:06:00	0.337	0.000	0.099	0.001	0.012	0.013
00:12:00	0.377	0.000	0.113	0.003	0.012	0.015
00:18:00	0.422	0.000	0.127	0.008	0.012	0.020
00:24:00	0.472	0.000	0.142	0.014	0.012	0.026
00:30:00	0.527	0.000	0.159	0.024	0.012	0.035
00:36:00	0.589	0.000	0.178	0.035	0.012	0.047
00:42:00	0.658	0.000	0.200	0.050	0.012	0.062
00:48:00	0.735	0.000	0.224	0.069	0.012	0.081
00:54:00	0.821	0.000	0.251	0.089	0.012	0.101
01:00:00	0.917	0.000	0.282	0.111	0.012	0.123
01:06:00	1.023	0.000	0.316	0.134	0.013	0.147
01:12:00	1.141	0.000	0.354	0.160	0.013	0.173
01:18:00	1.273	0.000	0.398	0.188	0.013	0.201
01:24:00	1.419	0.000	0.447	0.218	0.014	0.232
01:30:00	1.581	0.000	0.501	0.251	0.014	0.265
01:36:00	1.760	0.000	0.563	0.287	0.015	0.302
01:42:00	1.959	0.000	0.633	0.327	0.016	0.343
01:48:00	2.178	0.000	0.711	0.371	0.017	0.388
01:54:00	2.420	0.000	0.799	0.420	0.018	0.438
02:00:00	2.685	0.000	0.898	0.475	0.020	0.495
02:06:00	2.974	0.000	1.007	0.536	0.021	0.557
02:12:00	3.286	0.000	1.130	0.604	0.023	0.627
02:18:00	3.616	0.000	1.263	0.680	0.025	0.705
02:24:00	3.936	0.000	1.400	0.765	0.027	0.792
02:30:00	4.079	0.000	1.477	0.859	0.030	0.889
02:36:00	3.936	0.000	1.451	0.963	0.033	0.996
02:42:00	3.616	0.000	1.356	1.076	0.036	1.112
02:48:00	3.286	0.000	1.251	1.193	0.040	1.233
02:54:00	2.974	0.000	1.147	1.311	0.044	1.355
03:00:00	2.685	0.000	1.048	1.426	0.049	1.475
03:06:00	2.420	0.000	0.955	1.532	0.054	1.586
03:12:00	2.178	0.000	0.868	1.624	0.060	1.684
03:18:00	1.959	0.000	0.787	1.699	0.066	1.765
03:24:00	1.760	0.000	0.713	1.752	0.073	1.824

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
03:30:00	1.581	0.000	0.644	1.783	0.080	1.862
03:36:00	1.419	0.000	0.582	1.792	0.087	1.879
03:42:00	1.273	0.000	0.525	1.783	0.094	1.878
03:48:00	1.141	0.000	0.473	1.758	0.102	1.860
03:54:00	1.023	0.000	0.426	1.718	0.110	1.828
04:00:00	0.917	0.000	0.383	1.667	0.118	1.785
04:06:00	0.821	0.000	0.344	1.608	0.125	1.733
04:12:00	0.735	0.000	0.308	1.541	0.133	1.674
04:18:00	0.658	0.000	0.276	1.470	0.140	1.610
04:24:00	0.589	0.000	0.248	1.395	0.147	1.542
04:30:00	0.527	0.000	0.222	1.317	0.154	1.471
04:36:00	0.472	0.000	0.199	1.237	0.161	1.397
04:42:00	0.422	0.000	0.179	1.156	0.167	1.323
04:48:00	0.377	0.000	0.160	1.075	0.173	1.248
04:54:00	0.337	0.000	0.143	0.996	0.179	1.174
05:00:00	0.302	0.000	0.128	0.918	0.184	1.102
05:06:00	0.000	0.000	0.000	0.843	0.189	1.032
05:12:00	0.000	0.000	0.000	0.771	0.193	0.964
05:18:00	0.000	0.000	0.000	0.700	0.198	0.898
05:24:00	0.000	0.000	0.000	0.633	0.202	0.835
05:30:00	0.000	0.000	0.000	0.569	0.205	0.774
05:36:00	0.000	0.000	0.000	0.507	0.208	0.716
05:42:00	0.000	0.000	0.000	0.449	0.211	0.660
05:48:00	0.000	0.000	0.000	0.393	0.213	0.607
05:54:00	0.000	0.000	0.000	0.341	0.216	0.556
06:00:00	0.000	0.000	0.000	0.293	0.217	0.510
06:06:00	0.000	0.000	0.000	0.250	0.219	0.469
06:12:00	0.000	0.000	0.000	0.212	0.220	0.432
06:18:00	0.000	0.000	0.000	0.179	0.221	0.400
06:24:00	0.000	0.000	0.000	0.150	0.222	0.372
06:30:00	0.000	0.000	0.000	0.126	0.222	0.348
06:36:00	0.000	0.000	0.000	0.105	0.223	0.328
06:42:00	0.000	0.000	0.000	0.087	0.223	0.310
06:48:00	0.000	0.000	0.000	0.071	0.223	0.294
06:54:00	0.000	0.000	0.000	0.058	0.223	0.281
07:00:00	0.000	0.000	0.000	0.047	0.223	0.269

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
07:06:00	0.000	0.000	0.000	0.037	0.222	0.260
07:12:00	0.000	0.000	0.000	0.029	0.222	0.251
07:18:00	0.000	0.000	0.000	0.022	0.222	0.244
07:24:00	0.000	0.000	0.000	0.017	0.221	0.238
07:30:00	0.000	0.000	0.000	0.013	0.221	0.233
07:36:00	0.000	0.000	0.000	0.009	0.220	0.230
07:42:00	0.000	0.000	0.000	0.007	0.220	0.226
07:48:00	0.000	0.000	0.000	0.005	0.219	0.224
07:54:00	0.000	0.000	0.000	0.004	0.218	0.222
08:00:00	0.000	0.000	0.000	0.003	0.218	0.221
08:06:00	0.000	0.000	0.000	0.002	0.217	0.219
08:12:00	0.000	0.000	0.000	0.001	0.216	0.218
08:18:00	0.000	0.000	0.000	0.001	0.216	0.216
08:24:00	0.000	0.000	0.000	0.000	0.215	0.215
08:30:00	0.000	0.000	0.000	0.000	0.214	0.214
08:36:00	0.000	0.000	0.000	0.000	0.214	0.214
08:42:00	0.000	0.000	0.000	0.000	0.213	0.213
08:48:00	0.000	0.000	0.000	0.000	0.212	0.212
08:54:00	0.000	0.000	0.000	0.000	0.211	0.211
09:00:00	0.000	0.000	0.000	0.000	0.211	0.211
09:06:00	0.000	0.000	0.000	0.000	0.210	0.210
09:12:00	0.000	0.000	0.000	0.000	0.209	0.209
09:18:00	0.000	0.000	0.000	0.000	0.209	0.209
09:24:00	0.000	0.000	0.000	0.000	0.208	0.208
09:30:00	0.000	0.000	0.000	0.000	0.207	0.207
09:36:00	0.000	0.000	0.000	0.000	0.207	0.207
09:42:00	0.000	0.000	0.000	0.000	0.206	0.206
09:48:00	0.000	0.000	0.000	0.000	0.205	0.205
09:54:00	0.000	0.000	0.000	0.000	0.205	0.205
10:00:00	0.000	0.000	0.000	0.000	0.204	0.204
10:06:00	0.000	0.000	0.000	0.000	0.203	0.203
10:12:00	0.000	0.000	0.000	0.000	0.203	0.203
10:18:00	0.000	0.000	0.000	0.000	0.202	0.202
10:24:00	0.000	0.000	0.000	0.000	0.201	0.201
10:30:00	0.000	0.000	0.000	0.000	0.201	0.201
10:36:00	0.000	0.000	0.000	0.000	0.200	0.200

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
10:42:00	0.000	0.000	0.000	0.000	0.199	0.199
10:48:00	0.000	0.000	0.000	0.000	0.199	0.199
10:54:00	0.000	0.000	0.000	0.000	0.198	0.198
11:00:00	0.000	0.000	0.000	0.000	0.197	0.197
11:06:00	0.000	0.000	0.000	0.000	0.197	0.197
11:12:00	0.000	0.000	0.000	0.000	0.196	0.196
11:18:00	0.000	0.000	0.000	0.000	0.195	0.195
11:24:00	0.000	0.000	0.000	0.000	0.195	0.195
11:30:00	0.000	0.000	0.000	0.000	0.194	0.194
11:36:00	0.000	0.000	0.000	0.000	0.193	0.193
11:42:00	0.000	0.000	0.000	0.000	0.193	0.193
11:48:00	0.000	0.000	0.000	0.000	0.192	0.192
11:54:00	0.000	0.000	0.000	0.000	0.191	0.191
12:00:00	0.000	0.000	0.000	0.000	0.191	0.191
12:06:00	0.000	0.000	0.000	0.000	0.190	0.190
12:12:00	0.000	0.000	0.000	0.000	0.190	0.190
12:18:00	0.000	0.000	0.000	0.000	0.189	0.189
12:24:00	0.000	0.000	0.000	0.000	0.188	0.188
12:30:00	0.000	0.000	0.000	0.000	0.188	0.188
12:36:00	0.000	0.000	0.000	0.000	0.187	0.187
12:42:00	0.000	0.000	0.000	0.000	0.186	0.186
12:48:00	0.000	0.000	0.000	0.000	0.186	0.186
12:54:00	0.000	0.000	0.000	0.000	0.185	0.185
13:00:00	0.000	0.000	0.000	0.000	0.185	0.185
13:06:00	0.000	0.000	0.000	0.000	0.184	0.184
13:12:00	0.000	0.000	0.000	0.000	0.183	0.183
13:18:00	0.000	0.000	0.000	0.000	0.183	0.183
13:24:00	0.000	0.000	0.000	0.000	0.182	0.182
13:30:00	0.000	0.000	0.000	0.000	0.182	0.182
13:36:00	0.000	0.000	0.000	0.000	0.181	0.181
13:42:00	0.000	0.000	0.000	0.000	0.180	0.180
13:48:00	0.000	0.000	0.000	0.000	0.180	0.180
13:54:00	0.000	0.000	0.000	0.000	0.179	0.179
14:00:00	0.000	0.000	0.000	0.000	0.179	0.179
14:06:00	0.000	0.000	0.000	0.000	0.178	0.178
14:12:00	0.000	0.000	0.000	0.000	0.177	0.177

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
14:18:00	0.000	0.000	0.000	0.000	0.177	0.177
14:24:00	0.000	0.000	0.000	0.000	0.176	0.176
14:30:00	0.000	0.000	0.000	0.000	0.176	0.176
14:36:00	0.000	0.000	0.000	0.000	0.175	0.175
14:42:00	0.000	0.000	0.000	0.000	0.175	0.175
14:48:00	0.000	0.000	0.000	0.000	0.174	0.174
14:54:00	0.000	0.000	0.000	0.000	0.173	0.173
15:00:00	0.000	0.000	0.000	0.000	0.173	0.173
15:06:00	0.000	0.000	0.000	0.000	0.172	0.172
15:12:00	0.000	0.000	0.000	0.000	0.172	0.172
15:18:00	0.000	0.000	0.000	0.000	0.171	0.171
15:24:00	0.000	0.000	0.000	0.000	0.171	0.171
15:30:00	0.000	0.000	0.000	0.000	0.170	0.170
15:36:00	0.000	0.000	0.000	0.000	0.169	0.169
15:42:00	0.000	0.000	0.000	0.000	0.169	0.169
15:48:00	0.000	0.000	0.000	0.000	0.168	0.168
15:54:00	0.000	0.000	0.000	0.000	0.168	0.168
16:00:00	0.000	0.000	0.000	0.000	0.167	0.167
16:06:00	0.000	0.000	0.000	0.000	0.167	0.167
16:12:00	0.000	0.000	0.000	0.000	0.166	0.166
16:18:00	0.000	0.000	0.000	0.000	0.166	0.166
16:24:00	0.000	0.000	0.000	0.000	0.165	0.165
16:30:00	0.000	0.000	0.000	0.000	0.164	0.164
16:36:00	0.000	0.000	0.000	0.000	0.164	0.164
16:42:00	0.000	0.000	0.000	0.000	0.163	0.163
16:48:00	0.000	0.000	0.000	0.000	0.163	0.163
16:54:00	0.000	0.000	0.000	0.000	0.162	0.162
17:00:00	0.000	0.000	0.000	0.000	0.162	0.162
17:06:00	0.000	0.000	0.000	0.000	0.161	0.161
17:12:00	0.000	0.000	0.000	0.000	0.161	0.161
17:18:00	0.000	0.000	0.000	0.000	0.160	0.160
17:24:00	0.000	0.000	0.000	0.000	0.160	0.160
17:30:00	0.000	0.000	0.000	0.000	0.159	0.159
17:36:00	0.000	0.000	0.000	0.000	0.159	0.159
17:42:00	0.000	0.000	0.000	0.000	0.158	0.158
17:48:00	0.000	0.000	0.000	0.000	0.158	0.158

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
17:54:00	0.000	0.000	0.000	0.000	0.157	0.157
18:00:00	0.000	0.000	0.000	0.000	0.156	0.156
18:06:00	0.000	0.000	0.000	0.000	0.156	0.156
18:12:00	0.000	0.000	0.000	0.000	0.155	0.155
18:18:00	0.000	0.000	0.000	0.000	0.155	0.155
18:24:00	0.000	0.000	0.000	0.000	0.154	0.154
18:30:00	0.000	0.000	0.000	0.000	0.154	0.154
18:36:00	0.000	0.000	0.000	0.000	0.153	0.153
18:42:00	0.000	0.000	0.000	0.000	0.153	0.153
18:48:00	0.000	0.000	0.000	0.000	0.152	0.152
18:54:00	0.000	0.000	0.000	0.000	0.152	0.152
19:00:00	0.000	0.000	0.000	0.000	0.151	0.151
19:06:00	0.000	0.000	0.000	0.000	0.151	0.151
19:12:00	0.000	0.000	0.000	0.000	0.150	0.150
19:18:00	0.000	0.000	0.000	0.000	0.150	0.150
19:24:00	0.000	0.000	0.000	0.000	0.149	0.149
19:30:00	0.000	0.000	0.000	0.000	0.149	0.149
19:36:00	0.000	0.000	0.000	0.000	0.148	0.148
19:42:00	0.000	0.000	0.000	0.000	0.148	0.148
19:48:00	0.000	0.000	0.000	0.000	0.147	0.147
19:54:00	0.000	0.000	0.000	0.000	0.147	0.147
20:00:00	0.000	0.000	0.000	0.000	0.146	0.146
20:06:00	0.000	0.000	0.000	0.000	0.146	0.146
20:12:00	0.000	0.000	0.000	0.000	0.146	0.146
20:18:00	0.000	0.000	0.000	0.000	0.145	0.145
20:24:00	0.000	0.000	0.000	0.000	0.145	0.145
20:30:00	0.000	0.000	0.000	0.000	0.144	0.144
20:36:00	0.000	0.000	0.000	0.000	0.144	0.144
20:42:00	0.000	0.000	0.000	0.000	0.143	0.143
20:48:00	0.000	0.000	0.000	0.000	0.143	0.143
20:54:00	0.000	0.000	0.000	0.000	0.142	0.142
21:00:00	0.000	0.000	0.000	0.000	0.142	0.142
21:06:00	0.000	0.000	0.000	0.000	0.141	0.141
21:12:00	0.000	0.000	0.000	0.000	0.141	0.141
21:18:00	0.000	0.000	0.000	0.000	0.140	0.140
21:24:00	0.000	0.000	0.000	0.000	0.140	0.140

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
21:30:00	0.000	0.000	0.000	0.000	0.139	0.139
21:36:00	0.000	0.000	0.000	0.000	0.139	0.139
21:42:00	0.000	0.000	0.000	0.000	0.138	0.138
21:48:00	0.000	0.000	0.000	0.000	0.138	0.138
21:54:00	0.000	0.000	0.000	0.000	0.138	0.138
22:00:00	0.000	0.000	0.000	0.000	0.137	0.137
22:06:00	0.000	0.000	0.000	0.000	0.137	0.137
22:12:00	0.000	0.000	0.000	0.000	0.136	0.136
22:18:00	0.000	0.000	0.000	0.000	0.136	0.136
22:24:00	0.000	0.000	0.000	0.000	0.135	0.135
22:30:00	0.000	0.000	0.000	0.000	0.135	0.135
22:36:00	0.000	0.000	0.000	0.000	0.134	0.134
22:42:00	0.000	0.000	0.000	0.000	0.134	0.134
22:48:00	0.000	0.000	0.000	0.000	0.134	0.134
22:54:00	0.000	0.000	0.000	0.000	0.133	0.133
23:00:00	0.000	0.000	0.000	0.000	0.133	0.133
23:06:00	0.000	0.000	0.000	0.000	0.132	0.132
23:12:00	0.000	0.000	0.000	0.000	0.132	0.132
23:18:00	0.000	0.000	0.000	0.000	0.131	0.131
23:24:00	0.000	0.000	0.000	0.000	0.131	0.131
23:30:00	0.000	0.000	0.000	0.000	0.130	0.130
23:36:00	0.000	0.000	0.000	0.000	0.130	0.130
23:42:00	0.000	0.000	0.000	0.000	0.130	0.130
23:48:00	0.000	0.000	0.000	0.000	0.129	0.129
23:54:00	0.000	0.000	0.000	0.000	0.129	0.129
24:00:00	0.000	0.000	0.000	0.000	0.128	0.128
24:06:00	0.000	0.000	0.000	0.000	0.128	0.128
24:12:00	0.000	0.000	0.000	0.000	0.127	0.127
24:18:00	0.000	0.000	0.000	0.000	0.127	0.127
24:24:00	0.000	0.000	0.000	0.000	0.127	0.127
24:30:00	0.000	0.000	0.000	0.000	0.126	0.126
24:36:00	0.000	0.000	0.000	0.000	0.126	0.126
24:42:00	0.000	0.000	0.000	0.000	0.125	0.125
24:48:00	0.000	0.000	0.000	0.000	0.125	0.125
24:54:00	0.000	0.000	0.000	0.000	0.125	0.125
25:00:00	0.000	0.000	0.000	0.000	0.124	0.124

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
25:06:00	0.000	0.000	0.000	0.000	0.124	0.124
25:12:00	0.000	0.000	0.000	0.000	0.123	0.123
25:18:00	0.000	0.000	0.000	0.000	0.123	0.123
25:24:00	0.000	0.000	0.000	0.000	0.123	0.123
25:30:00	0.000	0.000	0.000	0.000	0.122	0.122
25:36:00	0.000	0.000	0.000	0.000	0.122	0.122
25:42:00	0.000	0.000	0.000	0.000	0.121	0.121
25:48:00	0.000	0.000	0.000	0.000	0.121	0.121
25:54:00	0.000	0.000	0.000	0.000	0.121	0.121
26:00:00	0.000	0.000	0.000	0.000	0.120	0.120
26:06:00	0.000	0.000	0.000	0.000	0.120	0.120
26:12:00	0.000	0.000	0.000	0.000	0.119	0.119
26:18:00	0.000	0.000	0.000	0.000	0.119	0.119
26:24:00	0.000	0.000	0.000	0.000	0.119	0.119
26:30:00	0.000	0.000	0.000	0.000	0.118	0.118
26:36:00	0.000	0.000	0.000	0.000	0.118	0.118
26:42:00	0.000	0.000	0.000	0.000	0.117	0.117
26:48:00	0.000	0.000	0.000	0.000	0.117	0.117
26:54:00	0.000	0.000	0.000	0.000	0.117	0.117
27:00:00	0.000	0.000	0.000	0.000	0.116	0.116
27:06:00	0.000	0.000	0.000	0.000	0.116	0.116
27:12:00	0.000	0.000	0.000	0.000	0.115	0.115
27:18:00	0.000	0.000	0.000	0.000	0.115	0.115
27:24:00	0.000	0.000	0.000	0.000	0.115	0.115
27:30:00	0.000	0.000	0.000	0.000	0.114	0.114
27:36:00	0.000	0.000	0.000	0.000	0.114	0.114
27:42:00	0.000	0.000	0.000	0.000	0.114	0.114
27:48:00	0.000	0.000	0.000	0.000	0.113	0.113
27:54:00	0.000	0.000	0.000	0.000	0.113	0.113
28:00:00	0.000	0.000	0.000	0.000	0.112	0.112
28:06:00	0.000	0.000	0.000	0.000	0.112	0.112
28:12:00	0.000	0.000	0.000	0.000	0.112	0.112
28:18:00	0.000	0.000	0.000	0.000	0.111	0.111
28:24:00	0.000	0.000	0.000	0.000	0.111	0.111
28:30:00	0.000	0.000	0.000	0.000	0.111	0.111
28:36:00	0.000	0.000	0.000	0.000	0.110	0.110

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
28:42:00	0.000	0.000	0.000	0.000	0.110	0.110
28:48:00	0.000	0.000	0.000	0.000	0.109	0.109
28:54:00	0.000	0.000	0.000	0.000	0.109	0.109
29:00:00	0.000	0.000	0.000	0.000	0.109	0.109
29:06:00	0.000	0.000	0.000	0.000	0.108	0.108
29:12:00	0.000	0.000	0.000	0.000	0.108	0.108
29:18:00	0.000	0.000	0.000	0.000	0.108	0.108
29:24:00	0.000	0.000	0.000	0.000	0.107	0.107
29:30:00	0.000	0.000	0.000	0.000	0.107	0.107
29:36:00	0.000	0.000	0.000	0.000	0.107	0.107
29:42:00	0.000	0.000	0.000	0.000	0.106	0.106
29:48:00	0.000	0.000	0.000	0.000	0.106	0.106
29:54:00	0.000	0.000	0.000	0.000	0.106	0.106
30:00:00	0.000	0.000	0.000	0.000	0.105	0.105
30:06:00	0.000	0.000	0.000	0.000	0.105	0.105
30:12:00	0.000	0.000	0.000	0.000	0.105	0.105
30:18:00	0.000	0.000	0.000	0.000	0.104	0.104
30:24:00	0.000	0.000	0.000	0.000	0.104	0.104
30:30:00	0.000	0.000	0.000	0.000	0.104	0.104
30:36:00	0.000	0.000	0.000	0.000	0.103	0.103
30:42:00	0.000	0.000	0.000	0.000	0.103	0.103
30:48:00	0.000	0.000	0.000	0.000	0.102	0.102
30:54:00	0.000	0.000	0.000	0.000	0.102	0.102
31:00:00	0.000	0.000	0.000	0.000	0.102	0.102
31:06:00	0.000	0.000	0.000	0.000	0.101	0.101
31:12:00	0.000	0.000	0.000	0.000	0.101	0.101
31:18:00	0.000	0.000	0.000	0.000	0.101	0.101
31:24:00	0.000	0.000	0.000	0.000	0.100	0.100
31:30:00	0.000	0.000	0.000	0.000	0.100	0.100
31:36:00	0.000	0.000	0.000	0.000	0.100	0.100
31:42:00	0.000	0.000	0.000	0.000	0.099	0.099
31:48:00	0.000	0.000	0.000	0.000	0.099	0.099
31:54:00	0.000	0.000	0.000	0.000	0.099	0.099
32:00:00	0.000	0.000	0.000	0.000	0.098	0.098
32:06:00	0.000	0.000	0.000	0.000	0.098	0.098
32:12:00	0.000	0.000	0.000	0.000	0.098	0.098

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
32:18:00	0.000	0.000	0.000	0.000	0.098	0.098
32:24:00	0.000	0.000	0.000	0.000	0.097	0.097
32:30:00	0.000	0.000	0.000	0.000	0.097	0.097
32:36:00	0.000	0.000	0.000	0.000	0.097	0.097
32:42:00	0.000	0.000	0.000	0.000	0.096	0.096
32:48:00	0.000	0.000	0.000	0.000	0.096	0.096
32:54:00	0.000	0.000	0.000	0.000	0.096	0.096
33:00:00	0.000	0.000	0.000	0.000	0.095	0.095
33:06:00	0.000	0.000	0.000	0.000	0.095	0.095
33:12:00	0.000	0.000	0.000	0.000	0.095	0.095
33:18:00	0.000	0.000	0.000	0.000	0.094	0.094
33:24:00	0.000	0.000	0.000	0.000	0.094	0.094
33:30:00	0.000	0.000	0.000	0.000	0.094	0.094
33:36:00	0.000	0.000	0.000	0.000	0.093	0.093
33:42:00	0.000	0.000	0.000	0.000	0.093	0.093
33:48:00	0.000	0.000	0.000	0.000	0.093	0.093
33:54:00	0.000	0.000	0.000	0.000	0.092	0.092
34:00:00	0.000	0.000	0.000	0.000	0.092	0.092
34:06:00	0.000	0.000	0.000	0.000	0.092	0.092
34:12:00	0.000	0.000	0.000	0.000	0.092	0.092
34:18:00	0.000	0.000	0.000	0.000	0.091	0.091
34:24:00	0.000	0.000	0.000	0.000	0.091	0.091
34:30:00	0.000	0.000	0.000	0.000	0.091	0.091
34:36:00	0.000	0.000	0.000	0.000	0.090	0.090
34:42:00	0.000	0.000	0.000	0.000	0.090	0.090
34:48:00	0.000	0.000	0.000	0.000	0.090	0.090
34:54:00	0.000	0.000	0.000	0.000	0.089	0.089
35:00:00	0.000	0.000	0.000	0.000	0.089	0.089
35:06:00	0.000	0.000	0.000	0.000	0.089	0.089
35:12:00	0.000	0.000	0.000	0.000	0.089	0.089
35:18:00	0.000	0.000	0.000	0.000	0.088	0.088
35:24:00	0.000	0.000	0.000	0.000	0.088	0.088
35:30:00	0.000	0.000	0.000	0.000	0.088	0.088
35:36:00	0.000	0.000	0.000	0.000	0.087	0.087
35:42:00	0.000	0.000	0.000	0.000	0.087	0.087
35:48:00	0.000	0.000	0.000	0.000	0.087	0.087

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
35:54:00	0.000	0.000	0.000	0.000	0.087	0.087
36:00:00	0.000	0.000	0.000	0.000	0.086	0.086
36:06:00	0.000	0.000	0.000	0.000	0.086	0.086
36:12:00	0.000	0.000	0.000	0.000	0.086	0.086
36:18:00	0.000	0.000	0.000	0.000	0.085	0.085
36:24:00	0.000	0.000	0.000	0.000	0.085	0.085
36:30:00	0.000	0.000	0.000	0.000	0.085	0.085
36:36:00	0.000	0.000	0.000	0.000	0.085	0.085
36:42:00	0.000	0.000	0.000	0.000	0.084	0.084
36:48:00	0.000	0.000	0.000	0.000	0.084	0.084
36:54:00	0.000	0.000	0.000	0.000	0.084	0.084
37:00:00	0.000	0.000	0.000	0.000	0.083	0.083
37:06:00	0.000	0.000	0.000	0.000	0.083	0.083
37:12:00	0.000	0.000	0.000	0.000	0.083	0.083
37:18:00	0.000	0.000	0.000	0.000	0.083	0.083
37:24:00	0.000	0.000	0.000	0.000	0.082	0.082
37:30:00	0.000	0.000	0.000	0.000	0.082	0.082
37:36:00	0.000	0.000	0.000	0.000	0.082	0.082
37:42:00	0.000	0.000	0.000	0.000	0.082	0.082
37:48:00	0.000	0.000	0.000	0.000	0.081	0.081
37:54:00	0.000	0.000	0.000	0.000	0.081	0.081
38:00:00	0.000	0.000	0.000	0.000	0.081	0.081
38:06:00	0.000	0.000	0.000	0.000	0.081	0.081
38:12:00	0.000	0.000	0.000	0.000	0.080	0.080
38:18:00	0.000	0.000	0.000	0.000	0.080	0.080
38:24:00	0.000	0.000	0.000	0.000	0.080	0.080
38:30:00	0.000	0.000	0.000	0.000	0.079	0.079
38:36:00	0.000	0.000	0.000	0.000	0.079	0.079
38:42:00	0.000	0.000	0.000	0.000	0.079	0.079
38:48:00	0.000	0.000	0.000	0.000	0.079	0.079
38:54:00	0.000	0.000	0.000	0.000	0.078	0.078
39:00:00	0.000	0.000	0.000	0.000	0.078	0.078
39:06:00	0.000	0.000	0.000	0.000	0.078	0.078
39:12:00	0.000	0.000	0.000	0.000	0.078	0.078
39:18:00	0.000	0.000	0.000	0.000	0.077	0.077
39:24:00	0.000	0.000	0.000	0.000	0.077	0.077

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
39:30:00	0.000	0.000	0.000	0.000	0.077	0.077
39:36:00	0.000	0.000	0.000	0.000	0.077	0.077
39:42:00	0.000	0.000	0.000	0.000	0.076	0.076
39:48:00	0.000	0.000	0.000	0.000	0.076	0.076
39:54:00	0.000	0.000	0.000	0.000	0.076	0.076
40:00:00	0.000	0.000	0.000	0.000	0.076	0.076
40:06:00	0.000	0.000	0.000	0.000	0.075	0.075
40:12:00	0.000	0.000	0.000	0.000	0.075	0.075
40:18:00	0.000	0.000	0.000	0.000	0.075	0.075
40:24:00	0.000	0.000	0.000	0.000	0.075	0.075
40:30:00	0.000	0.000	0.000	0.000	0.074	0.074
40:36:00	0.000	0.000	0.000	0.000	0.074	0.074
40:42:00	0.000	0.000	0.000	0.000	0.074	0.074
40:48:00	0.000	0.000	0.000	0.000	0.074	0.074
40:54:00	0.000	0.000	0.000	0.000	0.073	0.073
41:00:00	0.000	0.000	0.000	0.000	0.073	0.073
41:06:00	0.000	0.000	0.000	0.000	0.073	0.073
41:12:00	0.000	0.000	0.000	0.000	0.073	0.073
41:18:00	0.000	0.000	0.000	0.000	0.072	0.072
41:24:00	0.000	0.000	0.000	0.000	0.072	0.072
41:30:00	0.000	0.000	0.000	0.000	0.072	0.072
41:36:00	0.000	0.000	0.000	0.000	0.072	0.072
41:42:00	0.000	0.000	0.000	0.000	0.071	0.071
41:48:00	0.000	0.000	0.000	0.000	0.071	0.071
41:54:00	0.000	0.000	0.000	0.000	0.071	0.071
42:00:00	0.000	0.000	0.000	0.000	0.071	0.071
42:06:00	0.000	0.000	0.000	0.000	0.071	0.071
42:12:00	0.000	0.000	0.000	0.000	0.070	0.070
42:18:00	0.000	0.000	0.000	0.000	0.070	0.070
42:24:00	0.000	0.000	0.000	0.000	0.070	0.070
42:30:00	0.000	0.000	0.000	0.000	0.070	0.070
42:36:00	0.000	0.000	0.000	0.000	0.069	0.069
42:42:00	0.000	0.000	0.000	0.000	0.069	0.069
42:48:00	0.000	0.000	0.000	0.000	0.069	0.069
42:54:00	0.000	0.000	0.000	0.000	0.069	0.069
43:00:00	0.000	0.000	0.000	0.000	0.068	0.068

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
43:06:00	0.000	0.000	0.000	0.000	0.068	0.068
43:12:00	0.000	0.000	0.000	0.000	0.068	0.068
43:18:00	0.000	0.000	0.000	0.000	0.068	0.068
43:24:00	0.000	0.000	0.000	0.000	0.068	0.068
43:30:00	0.000	0.000	0.000	0.000	0.067	0.067
43:36:00	0.000	0.000	0.000	0.000	0.067	0.067
43:42:00	0.000	0.000	0.000	0.000	0.067	0.067
43:48:00	0.000	0.000	0.000	0.000	0.067	0.067
43:54:00	0.000	0.000	0.000	0.000	0.066	0.066
44:00:00	0.000	0.000	0.000	0.000	0.066	0.066
44:06:00	0.000	0.000	0.000	0.000	0.066	0.066
44:12:00	0.000	0.000	0.000	0.000	0.066	0.066
44:18:00	0.000	0.000	0.000	0.000	0.066	0.066
44:24:00	0.000	0.000	0.000	0.000	0.065	0.065
44:30:00	0.000	0.000	0.000	0.000	0.065	0.065
44:36:00	0.000	0.000	0.000	0.000	0.065	0.065
44:42:00	0.000	0.000	0.000	0.000	0.065	0.065
44:48:00	0.000	0.000	0.000	0.000	0.065	0.065
44:54:00	0.000	0.000	0.000	0.000	0.064	0.064
45:00:00	0.000	0.000	0.000	0.000	0.064	0.064
45:06:00	0.000	0.000	0.000	0.000	0.064	0.064
45:12:00	0.000	0.000	0.000	0.000	0.064	0.064
45:18:00	0.000	0.000	0.000	0.000	0.063	0.063
45:24:00	0.000	0.000	0.000	0.000	0.063	0.063
45:30:00	0.000	0.000	0.000	0.000	0.063	0.063
45:36:00	0.000	0.000	0.000	0.000	0.063	0.063
45:42:00	0.000	0.000	0.000	0.000	0.063	0.063
45:48:00	0.000	0.000	0.000	0.000	0.062	0.062
45:54:00	0.000	0.000	0.000	0.000	0.062	0.062
46:00:00	0.000	0.000	0.000	0.000	0.062	0.062
46:06:00	0.000	0.000	0.000	0.000	0.062	0.062
46:12:00	0.000	0.000	0.000	0.000	0.062	0.062
46:18:00	0.000	0.000	0.000	0.000	0.061	0.061
46:24:00	0.000	0.000	0.000	0.000	0.061	0.061
46:30:00	0.000	0.000	0.000	0.000	0.061	0.061
46:36:00	0.000	0.000	0.000	0.000	0.061	0.061

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
46:42:00	0.000	0.000	0.000	0.000	0.061	0.061
46:48:00	0.000	0.000	0.000	0.000	0.060	0.060
46:54:00	0.000	0.000	0.000	0.000	0.060	0.060
47:00:00	0.000	0.000	0.000	0.000	0.060	0.060
47:06:00	0.000	0.000	0.000	0.000	0.060	0.060
47:12:00	0.000	0.000	0.000	0.000	0.060	0.060
47:18:00	0.000	0.000	0.000	0.000	0.059	0.059
47:24:00	0.000	0.000	0.000	0.000	0.059	0.059
47:30:00	0.000	0.000	0.000	0.000	0.059	0.059
47:36:00	0.000	0.000	0.000	0.000	0.059	0.059
47:42:00	0.000	0.000	0.000	0.000	0.059	0.059
47:48:00	0.000	0.000	0.000	0.000	0.058	0.058
47:54:00	0.000	0.000	0.000	0.000	0.058	0.058
48:00:00	0.000	0.000	0.000	0.000	0.058	0.058
48:06:00	0.000	0.000	0.000	0.000	0.058	0.058
48:12:00	0.000	0.000	0.000	0.000	0.058	0.058
48:18:00	0.000	0.000	0.000	0.000	0.057	0.057
48:24:00	0.000	0.000	0.000	0.000	0.057	0.057
48:30:00	0.000	0.000	0.000	0.000	0.057	0.057
48:36:00	0.000	0.000	0.000	0.000	0.057	0.057
48:42:00	0.000	0.000	0.000	0.000	0.057	0.057
48:48:00	0.000	0.000	0.000	0.000	0.057	0.057
48:54:00	0.000	0.000	0.000	0.000	0.056	0.056
49:00:00	0.000	0.000	0.000	0.000	0.056	0.056
49:06:00	0.000	0.000	0.000	0.000	0.056	0.056
49:12:00	0.000	0.000	0.000	0.000	0.056	0.056
49:18:00	0.000	0.000	0.000	0.000	0.056	0.056
49:24:00	0.000	0.000	0.000	0.000	0.055	0.055
49:30:00	0.000	0.000	0.000	0.000	0.055	0.055
49:36:00	0.000	0.000	0.000	0.000	0.055	0.055
49:42:00	0.000	0.000	0.000	0.000	0.055	0.055
49:48:00	0.000	0.000	0.000	0.000	0.055	0.055
49:54:00	0.000	0.000	0.000	0.000	0.054	0.054
50:00:00	0.000	0.000	0.000	0.000	0.054	0.054
50:06:00	0.000	0.000	0.000	0.000	0.054	0.054
50:12:00	0.000	0.000	0.000	0.000	0.054	0.054

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
50:18:00	0.000	0.000	0.000	0.000	0.054	0.054
50:24:00	0.000	0.000	0.000	0.000	0.054	0.054
50:30:00	0.000	0.000	0.000	0.000	0.053	0.053
50:36:00	0.000	0.000	0.000	0.000	0.053	0.053
50:42:00	0.000	0.000	0.000	0.000	0.053	0.053
50:48:00	0.000	0.000	0.000	0.000	0.053	0.053
50:54:00	0.000	0.000	0.000	0.000	0.053	0.053
51:00:00	0.000	0.000	0.000	0.000	0.053	0.053
51:06:00	0.000	0.000	0.000	0.000	0.052	0.052
51:12:00	0.000	0.000	0.000	0.000	0.052	0.052
51:18:00	0.000	0.000	0.000	0.000	0.052	0.052
51:24:00	0.000	0.000	0.000	0.000	0.052	0.052
51:30:00	0.000	0.000	0.000	0.000	0.052	0.052
51:36:00	0.000	0.000	0.000	0.000	0.052	0.052
51:42:00	0.000	0.000	0.000	0.000	0.051	0.051
51:48:00	0.000	0.000	0.000	0.000	0.051	0.051
51:54:00	0.000	0.000	0.000	0.000	0.051	0.051
52:00:00	0.000	0.000	0.000	0.000	0.051	0.051
52:06:00	0.000	0.000	0.000	0.000	0.051	0.051
52:12:00	0.000	0.000	0.000	0.000	0.051	0.051
52:18:00	0.000	0.000	0.000	0.000	0.050	0.050
52:24:00	0.000	0.000	0.000	0.000	0.050	0.050
52:30:00	0.000	0.000	0.000	0.000	0.050	0.050
52:36:00	0.000	0.000	0.000	0.000	0.050	0.050
52:42:00	0.000	0.000	0.000	0.000	0.050	0.050
52:48:00	0.000	0.000	0.000	0.000	0.050	0.050
52:54:00	0.000	0.000	0.000	0.000	0.049	0.049
53:00:00	0.000	0.000	0.000	0.000	0.049	0.049
53:06:00	0.000	0.000	0.000	0.000	0.049	0.049
53:12:00	0.000	0.000	0.000	0.000	0.049	0.049
53:18:00	0.000	0.000	0.000	0.000	0.049	0.049
53:24:00	0.000	0.000	0.000	0.000	0.049	0.049
53:30:00	0.000	0.000	0.000	0.000	0.048	0.048
53:36:00	0.000	0.000	0.000	0.000	0.048	0.048
53:42:00	0.000	0.000	0.000	0.000	0.048	0.048
53:48:00	0.000	0.000	0.000	0.000	0.048	0.048

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
53:54:00	0.000	0.000	0.000	0.000	0.048	0.048
54:00:00	0.000	0.000	0.000	0.000	0.048	0.048
54:06:00	0.000	0.000	0.000	0.000	0.047	0.047
54:12:00	0.000	0.000	0.000	0.000	0.047	0.047
54:18:00	0.000	0.000	0.000	0.000	0.047	0.047
54:24:00	0.000	0.000	0.000	0.000	0.047	0.047
54:30:00	0.000	0.000	0.000	0.000	0.047	0.047
54:36:00	0.000	0.000	0.000	0.000	0.047	0.047
54:42:00	0.000	0.000	0.000	0.000	0.047	0.047
54:48:00	0.000	0.000	0.000	0.000	0.046	0.046
54:54:00	0.000	0.000	0.000	0.000	0.046	0.046
55:00:00	0.000	0.000	0.000	0.000	0.046	0.046
55:06:00	0.000	0.000	0.000	0.000	0.046	0.046
55:12:00	0.000	0.000	0.000	0.000	0.046	0.046
55:18:00	0.000	0.000	0.000	0.000	0.046	0.046
55:24:00	0.000	0.000	0.000	0.000	0.045	0.045
55:30:00	0.000	0.000	0.000	0.000	0.045	0.045
55:36:00	0.000	0.000	0.000	0.000	0.045	0.045
55:42:00	0.000	0.000	0.000	0.000	0.045	0.045
55:48:00	0.000	0.000	0.000	0.000	0.045	0.045
55:54:00	0.000	0.000	0.000	0.000	0.045	0.045
56:00:00	0.000	0.000	0.000	0.000	0.045	0.045
56:06:00	0.000	0.000	0.000	0.000	0.044	0.044
56:12:00	0.000	0.000	0.000	0.000	0.044	0.044
56:18:00	0.000	0.000	0.000	0.000	0.044	0.044
56:24:00	0.000	0.000	0.000	0.000	0.044	0.044
56:30:00	0.000	0.000	0.000	0.000	0.044	0.044
56:36:00	0.000	0.000	0.000	0.000	0.044	0.044
56:42:00	0.000	0.000	0.000	0.000	0.044	0.044
56:48:00	0.000	0.000	0.000	0.000	0.043	0.043
56:54:00	0.000	0.000	0.000	0.000	0.043	0.043
57:00:00	0.000	0.000	0.000	0.000	0.043	0.043
57:06:00	0.000	0.000	0.000	0.000	0.043	0.043
57:12:00	0.000	0.000	0.000	0.000	0.043	0.043
57:18:00	0.000	0.000	0.000	0.000	0.043	0.043
57:24:00	0.000	0.000	0.000	0.000	0.043	0.043

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
57:30:00	0.000	0.000	0.000	0.000	0.042	0.042
57:36:00	0.000	0.000	0.000	0.000	0.042	0.042
57:42:00	0.000	0.000	0.000	0.000	0.042	0.042
57:48:00	0.000	0.000	0.000	0.000	0.042	0.042
57:54:00	0.000	0.000	0.000	0.000	0.042	0.042
58:00:00	0.000	0.000	0.000	0.000	0.042	0.042
58:06:00	0.000	0.000	0.000	0.000	0.042	0.042
58:12:00	0.000	0.000	0.000	0.000	0.041	0.041
58:18:00	0.000	0.000	0.000	0.000	0.041	0.041
58:24:00	0.000	0.000	0.000	0.000	0.041	0.041
58:30:00	0.000	0.000	0.000	0.000	0.041	0.041
58:36:00	0.000	0.000	0.000	0.000	0.041	0.041
58:42:00	0.000	0.000	0.000	0.000	0.041	0.041
58:48:00	0.000	0.000	0.000	0.000	0.041	0.041
58:54:00	0.000	0.000	0.000	0.000	0.040	0.040
59:00:00	0.000	0.000	0.000	0.000	0.040	0.040
59:06:00	0.000	0.000	0.000	0.000	0.040	0.040
59:12:00	0.000	0.000	0.000	0.000	0.040	0.040
59:18:00	0.000	0.000	0.000	0.000	0.040	0.040
59:24:00	0.000	0.000	0.000	0.000	0.040	0.040
59:30:00	0.000	0.000	0.000	0.000	0.040	0.040
59:36:00	0.000	0.000	0.000	0.000	0.040	0.040
59:42:00	0.000	0.000	0.000	0.000	0.039	0.039
59:48:00	0.000	0.000	0.000	0.000	0.039	0.039
59:54:00	0.000	0.000	0.000	0.000	0.039	0.039
60:00:00	0.000	0.000	0.000	0.000	0.039	0.039
60:06:00	0.000	0.000	0.000	0.000	0.039	0.039
60:12:00	0.000	0.000	0.000	0.000	0.039	0.039
60:18:00	0.000	0.000	0.000	0.000	0.039	0.039
60:24:00	0.000	0.000	0.000	0.000	0.039	0.039
60:30:00	0.000	0.000	0.000	0.000	0.038	0.038
60:36:00	0.000	0.000	0.000	0.000	0.038	0.038
60:42:00	0.000	0.000	0.000	0.000	0.038	0.038
60:48:00	0.000	0.000	0.000	0.000	0.038	0.038
60:54:00	0.000	0.000	0.000	0.000	0.038	0.038
61:00:00	0.000	0.000	0.000	0.000	0.038	0.038

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
61:06:00	0.000	0.000	0.000	0.000	0.038	0.038
61:12:00	0.000	0.000	0.000	0.000	0.038	0.038
61:18:00	0.000	0.000	0.000	0.000	0.037	0.037
61:24:00	0.000	0.000	0.000	0.000	0.037	0.037
61:30:00	0.000	0.000	0.000	0.000	0.037	0.037
61:36:00	0.000	0.000	0.000	0.000	0.037	0.037
61:42:00	0.000	0.000	0.000	0.000	0.037	0.037
61:48:00	0.000	0.000	0.000	0.000	0.037	0.037
61:54:00	0.000	0.000	0.000	0.000	0.037	0.037
62:00:00	0.000	0.000	0.000	0.000	0.037	0.037
62:06:00	0.000	0.000	0.000	0.000	0.036	0.036
62:12:00	0.000	0.000	0.000	0.000	0.036	0.036
62:18:00	0.000	0.000	0.000	0.000	0.036	0.036
62:24:00	0.000	0.000	0.000	0.000	0.036	0.036
62:30:00	0.000	0.000	0.000	0.000	0.036	0.036
62:36:00	0.000	0.000	0.000	0.000	0.036	0.036
62:42:00	0.000	0.000	0.000	0.000	0.036	0.036
62:48:00	0.000	0.000	0.000	0.000	0.036	0.036
62:54:00	0.000	0.000	0.000	0.000	0.035	0.035
63:00:00	0.000	0.000	0.000	0.000	0.035	0.035
63:06:00	0.000	0.000	0.000	0.000	0.035	0.035
63:12:00	0.000	0.000	0.000	0.000	0.035	0.035
63:18:00	0.000	0.000	0.000	0.000	0.035	0.035
63:24:00	0.000	0.000	0.000	0.000	0.035	0.035
63:30:00	0.000	0.000	0.000	0.000	0.035	0.035
63:36:00	0.000	0.000	0.000	0.000	0.035	0.035
63:42:00	0.000	0.000	0.000	0.000	0.035	0.035
63:48:00	0.000	0.000	0.000	0.000	0.034	0.034
63:54:00	0.000	0.000	0.000	0.000	0.034	0.034
64:00:00	0.000	0.000	0.000	0.000	0.034	0.034
64:06:00	0.000	0.000	0.000	0.000	0.034	0.034
64:12:00	0.000	0.000	0.000	0.000	0.034	0.034
64:18:00	0.000	0.000	0.000	0.000	0.034	0.034
64:24:00	0.000	0.000	0.000	0.000	0.034	0.034
64:30:00	0.000	0.000	0.000	0.000	0.034	0.034
64:36:00	0.000	0.000	0.000	0.000	0.034	0.034

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
64:42:00	0.000	0.000	0.000	0.000	0.033	0.033
64:48:00	0.000	0.000	0.000	0.000	0.033	0.033
64:54:00	0.000	0.000	0.000	0.000	0.033	0.033
65:00:00	0.000	0.000	0.000	0.000	0.033	0.033
65:06:00	0.000	0.000	0.000	0.000	0.033	0.033
65:12:00	0.000	0.000	0.000	0.000	0.033	0.033
65:18:00	0.000	0.000	0.000	0.000	0.033	0.033
65:24:00	0.000	0.000	0.000	0.000	0.033	0.033
65:30:00	0.000	0.000	0.000	0.000	0.033	0.033
65:36:00	0.000	0.000	0.000	0.000	0.032	0.032
65:42:00	0.000	0.000	0.000	0.000	0.032	0.032
65:48:00	0.000	0.000	0.000	0.000	0.032	0.032
65:54:00	0.000	0.000	0.000	0.000	0.032	0.032
66:00:00	0.000	0.000	0.000	0.000	0.032	0.032
66:06:00	0.000	0.000	0.000	0.000	0.032	0.032
66:12:00	0.000	0.000	0.000	0.000	0.032	0.032
66:18:00	0.000	0.000	0.000	0.000	0.032	0.032
66:24:00	0.000	0.000	0.000	0.000	0.032	0.032
66:30:00	0.000	0.000	0.000	0.000	0.031	0.031
66:36:00	0.000	0.000	0.000	0.000	0.031	0.031
66:42:00	0.000	0.000	0.000	0.000	0.031	0.031
66:48:00	0.000	0.000	0.000	0.000	0.031	0.031
66:54:00	0.000	0.000	0.000	0.000	0.031	0.031
67:00:00	0.000	0.000	0.000	0.000	0.031	0.031
67:06:00	0.000	0.000	0.000	0.000	0.031	0.031
67:12:00	0.000	0.000	0.000	0.000	0.031	0.031
67:18:00	0.000	0.000	0.000	0.000	0.031	0.031
67:24:00	0.000	0.000	0.000	0.000	0.031	0.031
67:30:00	0.000	0.000	0.000	0.000	0.030	0.030
67:36:00	0.000	0.000	0.000	0.000	0.030	0.030
67:42:00	0.000	0.000	0.000	0.000	0.030	0.030
67:48:00	0.000	0.000	0.000	0.000	0.030	0.030
67:54:00	0.000	0.000	0.000	0.000	0.030	0.030
68:00:00	0.000	0.000	0.000	0.000	0.030	0.030
68:06:00	0.000	0.000	0.000	0.000	0.030	0.030
68:12:00	0.000	0.000	0.000	0.000	0.030	0.030

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
68:18:00	0.000	0.000	0.000	0.000	0.030	0.030
68:24:00	0.000	0.000	0.000	0.000	0.030	0.030
68:30:00	0.000	0.000	0.000	0.000	0.029	0.029
68:36:00	0.000	0.000	0.000	0.000	0.029	0.029
68:42:00	0.000	0.000	0.000	0.000	0.029	0.029
68:48:00	0.000	0.000	0.000	0.000	0.029	0.029
68:54:00	0.000	0.000	0.000	0.000	0.029	0.029
69:00:00	0.000	0.000	0.000	0.000	0.029	0.029
69:06:00	0.000	0.000	0.000	0.000	0.029	0.029
69:12:00	0.000	0.000	0.000	0.000	0.029	0.029
69:18:00	0.000	0.000	0.000	0.000	0.029	0.029
69:24:00	0.000	0.000	0.000	0.000	0.029	0.029
69:30:00	0.000	0.000	0.000	0.000	0.029	0.029
69:36:00	0.000	0.000	0.000	0.000	0.028	0.028
69:42:00	0.000	0.000	0.000	0.000	0.028	0.028
69:48:00	0.000	0.000	0.000	0.000	0.028	0.028
69:54:00	0.000	0.000	0.000	0.000	0.028	0.028
70:00:00	0.000	0.000	0.000	0.000	0.028	0.028
70:06:00	0.000	0.000	0.000	0.000	0.028	0.028
70:12:00	0.000	0.000	0.000	0.000	0.028	0.028
70:18:00	0.000	0.000	0.000	0.000	0.028	0.028
70:24:00	0.000	0.000	0.000	0.000	0.028	0.028
70:30:00	0.000	0.000	0.000	0.000	0.028	0.028
70:36:00	0.000	0.000	0.000	0.000	0.027	0.027
70:42:00	0.000	0.000	0.000	0.000	0.027	0.027
70:48:00	0.000	0.000	0.000	0.000	0.027	0.027
70:54:00	0.000	0.000	0.000	0.000	0.027	0.027
71:00:00	0.000	0.000	0.000	0.000	0.027	0.027
71:06:00	0.000	0.000	0.000	0.000	0.027	0.027
71:12:00	0.000	0.000	0.000	0.000	0.027	0.027
71:18:00	0.000	0.000	0.000	0.000	0.027	0.027
71:24:00	0.000	0.000	0.000	0.000	0.027	0.027
71:30:00	0.000	0.000	0.000	0.000	0.027	0.027
71:36:00	0.000	0.000	0.000	0.000	0.027	0.027
71:42:00	0.000	0.000	0.000	0.000	0.027	0.027
71:48:00	0.000	0.000	0.000	0.000	0.026	0.026

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
71:54:00	0.000	0.000	0.000	0.000	0.026	0.026
72:00:00	0.000	0.000	0.000	0.000	0.026	0.026
72:06:00	0.000	0.000	0.000	0.000	0.026	0.026
72:12:00	0.000	0.000	0.000	0.000	0.026	0.026
72:18:00	0.000	0.000	0.000	0.000	0.026	0.026
72:24:00	0.000	0.000	0.000	0.000	0.026	0.026
72:30:00	0.000	0.000	0.000	0.000	0.026	0.026
72:36:00	0.000	0.000	0.000	0.000	0.026	0.026
72:42:00	0.000	0.000	0.000	0.000	0.026	0.026
72:48:00	0.000	0.000	0.000	0.000	0.026	0.026
72:54:00	0.000	0.000	0.000	0.000	0.025	0.025
73:00:00	0.000	0.000	0.000	0.000	0.025	0.025
73:06:00	0.000	0.000	0.000	0.000	0.025	0.025
73:12:00	0.000	0.000	0.000	0.000	0.025	0.025
73:18:00	0.000	0.000	0.000	0.000	0.025	0.025
73:24:00	0.000	0.000	0.000	0.000	0.025	0.025
73:30:00	0.000	0.000	0.000	0.000	0.025	0.025
73:36:00	0.000	0.000	0.000	0.000	0.025	0.025
73:42:00	0.000	0.000	0.000	0.000	0.025	0.025
73:48:00	0.000	0.000	0.000	0.000	0.025	0.025
73:54:00	0.000	0.000	0.000	0.000	0.025	0.025
74:00:00	0.000	0.000	0.000	0.000	0.025	0.025
74:06:00	0.000	0.000	0.000	0.000	0.024	0.024
74:12:00	0.000	0.000	0.000	0.000	0.024	0.024
74:18:00	0.000	0.000	0.000	0.000	0.024	0.024
74:24:00	0.000	0.000	0.000	0.000	0.024	0.024
74:30:00	0.000	0.000	0.000	0.000	0.024	0.024
74:36:00	0.000	0.000	0.000	0.000	0.024	0.024
74:42:00	0.000	0.000	0.000	0.000	0.024	0.024
74:48:00	0.000	0.000	0.000	0.000	0.024	0.024
74:54:00	0.000	0.000	0.000	0.000	0.024	0.024
75:00:00	0.000	0.000	0.000	0.000	0.024	0.024
75:06:00	0.000	0.000	0.000	0.000	0.024	0.024
75:12:00	0.000	0.000	0.000	0.000	0.024	0.024
75:18:00	0.000	0.000	0.000	0.000	0.024	0.024
75:24:00	0.000	0.000	0.000	0.000	0.023	0.023

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
75:30:00	0.000	0.000	0.000	0.000	0.023	0.023
75:36:00	0.000	0.000	0.000	0.000	0.023	0.023
75:42:00	0.000	0.000	0.000	0.000	0.023	0.023
75:48:00	0.000	0.000	0.000	0.000	0.023	0.023
75:54:00	0.000	0.000	0.000	0.000	0.023	0.023
76:00:00	0.000	0.000	0.000	0.000	0.023	0.023
76:06:00	0.000	0.000	0.000	0.000	0.023	0.023
76:12:00	0.000	0.000	0.000	0.000	0.023	0.023
76:18:00	0.000	0.000	0.000	0.000	0.023	0.023
76:24:00	0.000	0.000	0.000	0.000	0.023	0.023
76:30:00	0.000	0.000	0.000	0.000	0.023	0.023
76:36:00	0.000	0.000	0.000	0.000	0.023	0.023
76:42:00	0.000	0.000	0.000	0.000	0.022	0.022
76:48:00	0.000	0.000	0.000	0.000	0.022	0.022
76:54:00	0.000	0.000	0.000	0.000	0.022	0.022
77:00:00	0.000	0.000	0.000	0.000	0.022	0.022
77:06:00	0.000	0.000	0.000	0.000	0.022	0.022
77:12:00	0.000	0.000	0.000	0.000	0.022	0.022
77:18:00	0.000	0.000	0.000	0.000	0.022	0.022
77:24:00	0.000	0.000	0.000	0.000	0.022	0.022
77:30:00	0.000	0.000	0.000	0.000	0.022	0.022
77:36:00	0.000	0.000	0.000	0.000	0.022	0.022
77:42:00	0.000	0.000	0.000	0.000	0.022	0.022
77:48:00	0.000	0.000	0.000	0.000	0.022	0.022
77:54:00	0.000	0.000	0.000	0.000	0.022	0.022
78:00:00	0.000	0.000	0.000	0.000	0.022	0.022
78:06:00	0.000	0.000	0.000	0.000	0.021	0.021
78:12:00	0.000	0.000	0.000	0.000	0.021	0.021
78:18:00	0.000	0.000	0.000	0.000	0.021	0.021
78:24:00	0.000	0.000	0.000	0.000	0.021	0.021
78:30:00	0.000	0.000	0.000	0.000	0.021	0.021
78:36:00	0.000	0.000	0.000	0.000	0.021	0.021
78:42:00	0.000	0.000	0.000	0.000	0.021	0.021
78:48:00	0.000	0.000	0.000	0.000	0.021	0.021
78:54:00	0.000	0.000	0.000	0.000	0.021	0.021
79:00:00	0.000	0.000	0.000	0.000	0.021	0.021

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
79:06:00	0.000	0.000	0.000	0.000	0.021	0.021
79:12:00	0.000	0.000	0.000	0.000	0.021	0.021
79:18:00	0.000	0.000	0.000	0.000	0.021	0.021
79:24:00	0.000	0.000	0.000	0.000	0.021	0.021
79:30:00	0.000	0.000	0.000	0.000	0.020	0.020
79:36:00	0.000	0.000	0.000	0.000	0.020	0.020
79:42:00	0.000	0.000	0.000	0.000	0.020	0.020
79:48:00	0.000	0.000	0.000	0.000	0.020	0.020
79:54:00	0.000	0.000	0.000	0.000	0.020	0.020
80:00:00	0.000	0.000	0.000	0.000	0.020	0.020
80:06:00	0.000	0.000	0.000	0.000	0.020	0.020
80:12:00	0.000	0.000	0.000	0.000	0.020	0.020
80:18:00	0.000	0.000	0.000	0.000	0.020	0.020
80:24:00	0.000	0.000	0.000	0.000	0.020	0.020
80:30:00	0.000	0.000	0.000	0.000	0.020	0.020
80:36:00	0.000	0.000	0.000	0.000	0.020	0.020
80:42:00	0.000	0.000	0.000	0.000	0.020	0.020
80:48:00	0.000	0.000	0.000	0.000	0.020	0.020
80:54:00	0.000	0.000	0.000	0.000	0.020	0.020
81:00:00	0.000	0.000	0.000	0.000	0.019	0.019
81:06:00	0.000	0.000	0.000	0.000	0.019	0.019
81:12:00	0.000	0.000	0.000	0.000	0.019	0.019
81:18:00	0.000	0.000	0.000	0.000	0.019	0.019
81:24:00	0.000	0.000	0.000	0.000	0.019	0.019
81:30:00	0.000	0.000	0.000	0.000	0.019	0.019
81:36:00	0.000	0.000	0.000	0.000	0.019	0.019
81:42:00	0.000	0.000	0.000	0.000	0.019	0.019
81:48:00	0.000	0.000	0.000	0.000	0.019	0.019
81:54:00	0.000	0.000	0.000	0.000	0.019	0.019
82:00:00	0.000	0.000	0.000	0.000	0.019	0.019
82:06:00	0.000	0.000	0.000	0.000	0.019	0.019
82:12:00	0.000	0.000	0.000	0.000	0.019	0.019
82:18:00	0.000	0.000	0.000	0.000	0.019	0.019
82:24:00	0.000	0.000	0.000	0.000	0.019	0.019
82:30:00	0.000	0.000	0.000	0.000	0.019	0.019
82:36:00	0.000	0.000	0.000	0.000	0.018	0.018

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
82:42:00	0.000	0.000	0.000	0.000	0.018	0.018
82:48:00	0.000	0.000	0.000	0.000	0.018	0.018
82:54:00	0.000	0.000	0.000	0.000	0.018	0.018
83:00:00	0.000	0.000	0.000	0.000	0.018	0.018
83:06:00	0.000	0.000	0.000	0.000	0.018	0.018
83:12:00	0.000	0.000	0.000	0.000	0.018	0.018
83:18:00	0.000	0.000	0.000	0.000	0.018	0.018
83:24:00	0.000	0.000	0.000	0.000	0.018	0.018
83:30:00	0.000	0.000	0.000	0.000	0.018	0.018
83:36:00	0.000	0.000	0.000	0.000	0.018	0.018
83:42:00	0.000	0.000	0.000	0.000	0.018	0.018
83:48:00	0.000	0.000	0.000	0.000	0.018	0.018
83:54:00	0.000	0.000	0.000	0.000	0.018	0.018
84:00:00	0.000	0.000	0.000	0.000	0.018	0.018
84:06:00	0.000	0.000	0.000	0.000	0.018	0.018
84:12:00	0.000	0.000	0.000	0.000	0.018	0.018
84:18:00	0.000	0.000	0.000	0.000	0.017	0.017
84:24:00	0.000	0.000	0.000	0.000	0.017	0.017
84:30:00	0.000	0.000	0.000	0.000	0.017	0.017
84:36:00	0.000	0.000	0.000	0.000	0.017	0.017
84:42:00	0.000	0.000	0.000	0.000	0.017	0.017
84:48:00	0.000	0.000	0.000	0.000	0.017	0.017
84:54:00	0.000	0.000	0.000	0.000	0.017	0.017
85:00:00	0.000	0.000	0.000	0.000	0.017	0.017
85:06:00	0.000	0.000	0.000	0.000	0.017	0.017
85:12:00	0.000	0.000	0.000	0.000	0.017	0.017
85:18:00	0.000	0.000	0.000	0.000	0.017	0.017
85:24:00	0.000	0.000	0.000	0.000	0.017	0.017
85:30:00	0.000	0.000	0.000	0.000	0.017	0.017
85:36:00	0.000	0.000	0.000	0.000	0.017	0.017
85:42:00	0.000	0.000	0.000	0.000	0.017	0.017
85:48:00	0.000	0.000	0.000	0.000	0.017	0.017
85:54:00	0.000	0.000	0.000	0.000	0.017	0.017
86:00:00	0.000	0.000	0.000	0.000	0.017	0.017
86:06:00	0.000	0.000	0.000	0.000	0.016	0.016
86:12:00	0.000	0.000	0.000	0.000	0.016	0.016

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Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
86:18:00	0.000	0.000	0.000	0.000	0.016	0.016
86:24:00	0.000	0.000	0.000	0.000	0.016	0.016
86:30:00	0.000	0.000	0.000	0.000	0.016	0.016
86:36:00	0.000	0.000	0.000	0.000	0.016	0.016
86:42:00	0.000	0.000	0.000	0.000	0.016	0.016
86:48:00	0.000	0.000	0.000	0.000	0.016	0.016
86:54:00	0.000	0.000	0.000	0.000	0.016	0.016
87:00:00	0.000	0.000	0.000	0.000	0.016	0.016
87:06:00	0.000	0.000	0.000	0.000	0.016	0.016
87:12:00	0.000	0.000	0.000	0.000	0.016	0.016
87:18:00	0.000	0.000	0.000	0.000	0.016	0.016
87:24:00	0.000	0.000	0.000	0.000	0.016	0.016
87:30:00	0.000	0.000	0.000	0.000	0.016	0.016
87:36:00	0.000	0.000	0.000	0.000	0.016	0.016
87:42:00	0.000	0.000	0.000	0.000	0.016	0.016
87:48:00	0.000	0.000	0.000	0.000	0.016	0.016
87:54:00	0.000	0.000	0.000	0.000	0.016	0.016
88:00:00	0.000	0.000	0.000	0.000	0.015	0.015
88:06:00	0.000	0.000	0.000	0.000	0.015	0.015
88:12:00	0.000	0.000	0.000	0.000	0.015	0.015
88:18:00	0.000	0.000	0.000	0.000	0.015	0.015
88:24:00	0.000	0.000	0.000	0.000	0.015	0.015
88:30:00	0.000	0.000	0.000	0.000	0.015	0.015
88:36:00	0.000	0.000	0.000	0.000	0.015	0.015
88:42:00	0.000	0.000	0.000	0.000	0.015	0.015
88:48:00	0.000	0.000	0.000	0.000	0.015	0.015
88:54:00	0.000	0.000	0.000	0.000	0.015	0.015
89:00:00	0.000	0.000	0.000	0.000	0.015	0.015
89:06:00	0.000	0.000	0.000	0.000	0.015	0.015
89:12:00	0.000	0.000	0.000	0.000	0.015	0.015
89:18:00	0.000	0.000	0.000	0.000	0.015	0.015
89:24:00	0.000	0.000	0.000	0.000	0.015	0.015
89:30:00	0.000	0.000	0.000	0.000	0.015	0.015
89:36:00	0.000	0.000	0.000	0.000	0.015	0.015
89:42:00	0.000	0.000	0.000	0.000	0.015	0.015
89:48:00	0.000	0.000	0.000	0.000	0.015	0.015

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
89:54:00	0.000	0.000	0.000	0.000	0.015	0.015
90:00:00	0.000	0.000	0.000	0.000	0.014	0.014
90:06:00	0.000	0.000	0.000	0.000	0.014	0.014
90:12:00	0.000	0.000	0.000	0.000	0.014	0.014
90:18:00	0.000	0.000	0.000	0.000	0.014	0.014
90:24:00	0.000	0.000	0.000	0.000	0.014	0.014
90:30:00	0.000	0.000	0.000	0.000	0.014	0.014
90:36:00	0.000	0.000	0.000	0.000	0.014	0.014
90:42:00	0.000	0.000	0.000	0.000	0.014	0.014
90:48:00	0.000	0.000	0.000	0.000	0.014	0.014
90:54:00	0.000	0.000	0.000	0.000	0.014	0.014
91:00:00	0.000	0.000	0.000	0.000	0.014	0.014
91:06:00	0.000	0.000	0.000	0.000	0.014	0.014
91:12:00	0.000	0.000	0.000	0.000	0.014	0.014
91:18:00	0.000	0.000	0.000	0.000	0.014	0.014
91:24:00	0.000	0.000	0.000	0.000	0.014	0.014
91:30:00	0.000	0.000	0.000	0.000	0.014	0.014
91:36:00	0.000	0.000	0.000	0.000	0.014	0.014
91:42:00	0.000	0.000	0.000	0.000	0.014	0.014
91:48:00	0.000	0.000	0.000	0.000	0.014	0.014
91:54:00	0.000	0.000	0.000	0.000	0.014	0.014
92:00:00	0.000	0.000	0.000	0.000	0.014	0.014
92:06:00	0.000	0.000	0.000	0.000	0.014	0.014
92:12:00	0.000	0.000	0.000	0.000	0.013	0.013
92:18:00	0.000	0.000	0.000	0.000	0.013	0.013
92:24:00	0.000	0.000	0.000	0.000	0.013	0.013
92:30:00	0.000	0.000	0.000	0.000	0.013	0.013
92:36:00	0.000	0.000	0.000	0.000	0.013	0.013
92:42:00	0.000	0.000	0.000	0.000	0.013	0.013
92:48:00	0.000	0.000	0.000	0.000	0.013	0.013
92:54:00	0.000	0.000	0.000	0.000	0.013	0.013
93:00:00	0.000	0.000	0.000	0.000	0.013	0.013
93:06:00	0.000	0.000	0.000	0.000	0.013	0.013
93:12:00	0.000	0.000	0.000	0.000	0.013	0.013
93:18:00	0.000	0.000	0.000	0.000	0.013	0.013
93:24:00	0.000	0.000	0.000	0.000	0.013	0.013

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
93:30:00	0.000	0.000	0.000	0.000	0.013	0.013
93:36:00	0.000	0.000	0.000	0.000	0.013	0.013
93:42:00	0.000	0.000	0.000	0.000	0.013	0.013
93:48:00	0.000	0.000	0.000	0.000	0.013	0.013
93:54:00	0.000	0.000	0.000	0.000	0.013	0.013
94:00:00	0.000	0.000	0.000	0.000	0.013	0.013
94:06:00	0.000	0.000	0.000	0.000	0.013	0.013
94:12:00	0.000	0.000	0.000	0.000	0.013	0.013
94:18:00	0.000	0.000	0.000	0.000	0.013	0.013
94:24:00	0.000	0.000	0.000	0.000	0.013	0.013
94:30:00	0.000	0.000	0.000	0.000	0.012	0.012
94:36:00	0.000	0.000	0.000	0.000	0.012	0.012
94:42:00	0.000	0.000	0.000	0.000	0.012	0.012
94:48:00	0.000	0.000	0.000	0.000	0.012	0.012
94:54:00	0.000	0.000	0.000	0.000	0.012	0.012
95:00:00	0.000	0.000	0.000	0.000	0.012	0.012
95:06:00	0.000	0.000	0.000	0.000	0.012	0.012
95:12:00	0.000	0.000	0.000	0.000	0.012	0.012
95:18:00	0.000	0.000	0.000	0.000	0.012	0.012
95:24:00	0.000	0.000	0.000	0.000	0.012	0.012
95:30:00	0.000	0.000	0.000	0.000	0.012	0.012
95:36:00	0.000	0.000	0.000	0.000	0.012	0.012
95:42:00	0.000	0.000	0.000	0.000	0.012	0.012
95:48:00	0.000	0.000	0.000	0.000	0.012	0.012

Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Appendix

Catchment descriptors *

Name	Value	User-defined value used?
Area (km^2)	0.62	No
ALTBAR	228	No
ASPBAR	91	No
ASPVAR	0.64	No
BFIHOST	0.62	No
BFIHOST19	0.62	No
DPLBAR (km)	1.03	No
DPSBAR (mkm^{-1})	80.9	No
FARL	1	No
LDP	1.99	No
PROPWET (mm)	0.57	No
RMED1H	10.9	No
RMED1D	39.9	No
RMED2D	52.6	No
SAAR (mm)	1025	No
SAAR4170 (mm)	1000	No
SPRHOST	34	No
Urbext2000	0.41 [0.17]	**Yes**
Urbext1990	0.15	No
URBCONC	0.81	No
URBLOC	0.69	No
DDF parameter C	-0.03	No
DDF parameter D1	0.38	No
DDF parameter D2	0.4	No
DDF parameter D3	0.32	No
DDF parameter E	0.31	No
DDF parameter F	2.46	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.37	No
DDF parameter D2 (1km grid value)	0.41	No
DDF parameter D3 (1km grid value)	0.31	No
DDF parameter E (1km grid value)	0.31	No
DDF parameter F (1km grid value)	2.44	No

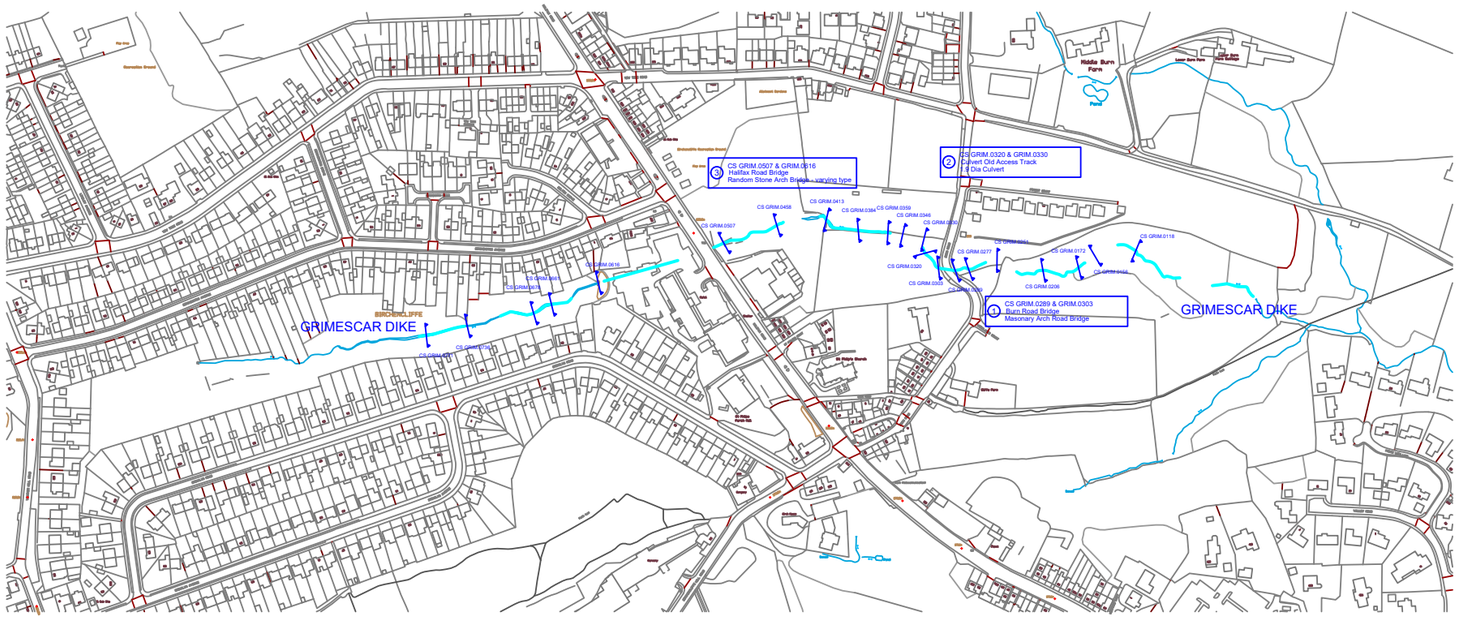
Values in square brackets are the original values loaded from the FEH Web Service or FEH CD-ROM

Appendix 2 – Model Files and Modelling Log

River/Catchment Name	BuRN Road, Huddersfield
Code	BRN
Modeller	Helena Du-Roe

Model Run ID	Scenario Description	Setup	Run	Return Period	TUFLOW Control File	Geometry Control File	Boundary Condtion Control File	INBoundary Conditions Database	Estry Control File	Stability/Health	Mannings
001	Existing Freeflowing structures	Yes	Yes	Q20	BRN_~e~_001.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_001.ecf	OK	BRN_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q100	BRN_~e~_001.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_001.ecf	OK	BRN_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q100+31%CC	BRN_~e~_001.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_001.ecf	OK	BRN_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q100+51%CC	BRN_~e~_001.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_001.ecf	OK	BRN_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q1000	BRN_~e~_001.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_001.ecf	OK	BRN_001.tmf
002a	Existing 50% culvert blockage (Culvert 1)	Yes	Yes	Q100	BRN_~e~_002a.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_002a.ecf	OK	BRN_001.tmf
002b	Existing 50% culvert blockage (Culvert 4)	Yes	Yes	Q100	BRN_~e~_002b.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_002b.ecf	OK	BRN_001.tmf
003a	Downstream Boundary +0.5m	Yes	Yes	Q100	BRN_~e~_003a.tcf	BRN_001.tgc	BRN_003a.tbc	bc_dbase.csv	BRN_~e~_003a.ecf	OK	BRN_001.tmf
004a	Mannings Roughness +20%	Yes	Yes	Q100	BRN_~e~_004a.tcf	BRN_004a.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_004a.ecf	OK	BRN_001.tmf
004b	Mannings Roughness -20%	Yes	Yes	Q100	BRN_~e~_004b.tcf	BRN_004b.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_004b.ecf	OK	BRN_001.tmf
005	50% Inflow downstream of Halifax Road Culvert	Yes	Yes	Q1000	BRN_~e~_005.tcf	BRN_001.tgc	BRN_001.tbc	bc_dbase.csv	BRN_~e~_005.ecf	OK	BRN_001.tmf

Appendix 3 – Detailed Channel Survey



STRUCTURE LIST:
GRIMESCAR DIKE

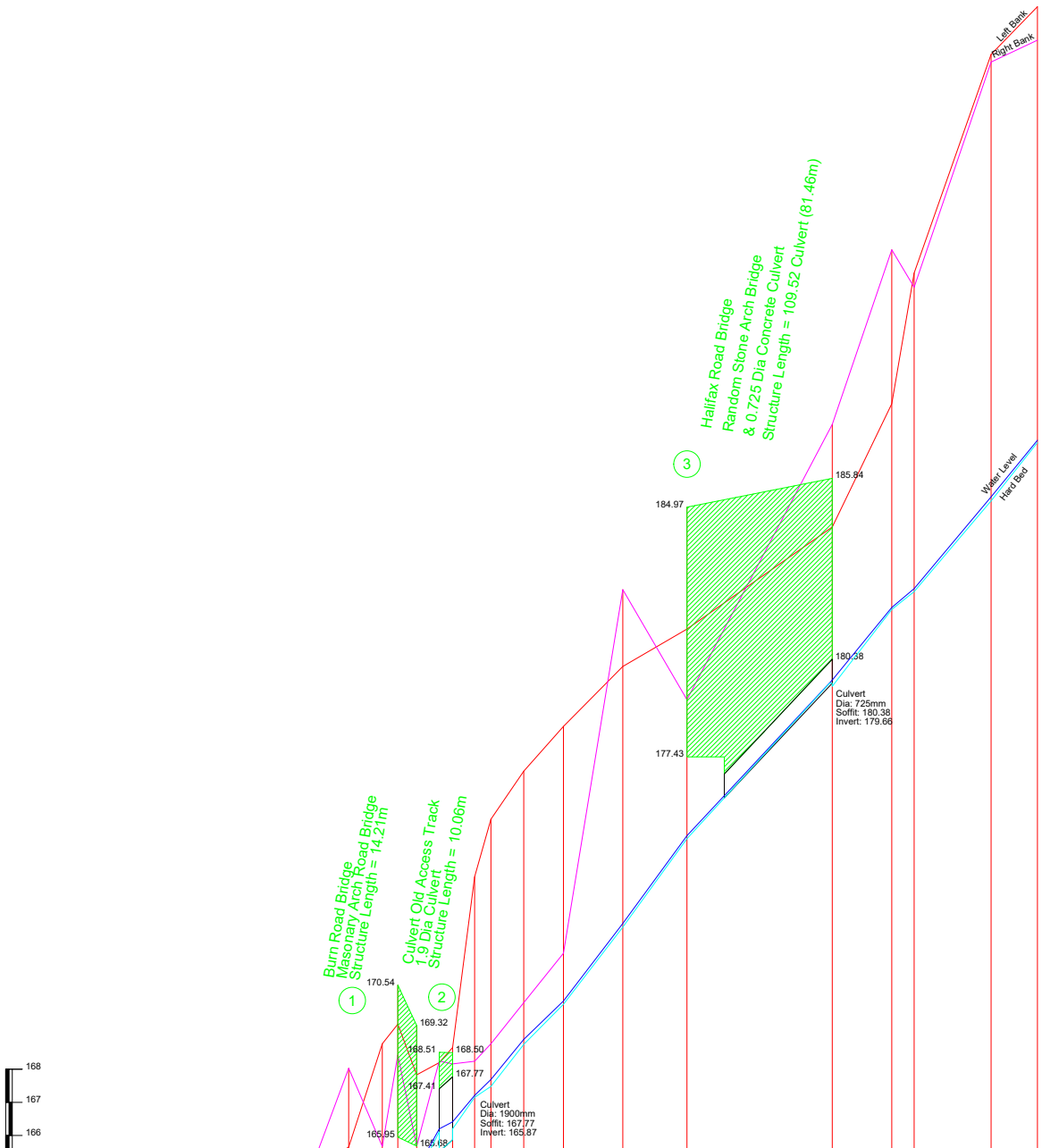
1. CS GRIM.0289 & GRIM.0303
   Burn Road Bridge
   Masonary Arch Road Bridge
2. CS GRIM.0320 & GRIM.0330
   Culvert Old Access Track
   1.9 Dia Culvert
3. CS GRIM.0507 & GRIM.0616
   Halifax Road Bridge
   Random Stone Arch Bridge - varying type

STRUCTURE NUMBER
CROSS SECTION LOCATION S1
WATERCOURSE CENTRELINE & SURVEYED EXTENT
SURVEYED BY GNSS TO OSNG. LEVEL DATUM OSGM15.

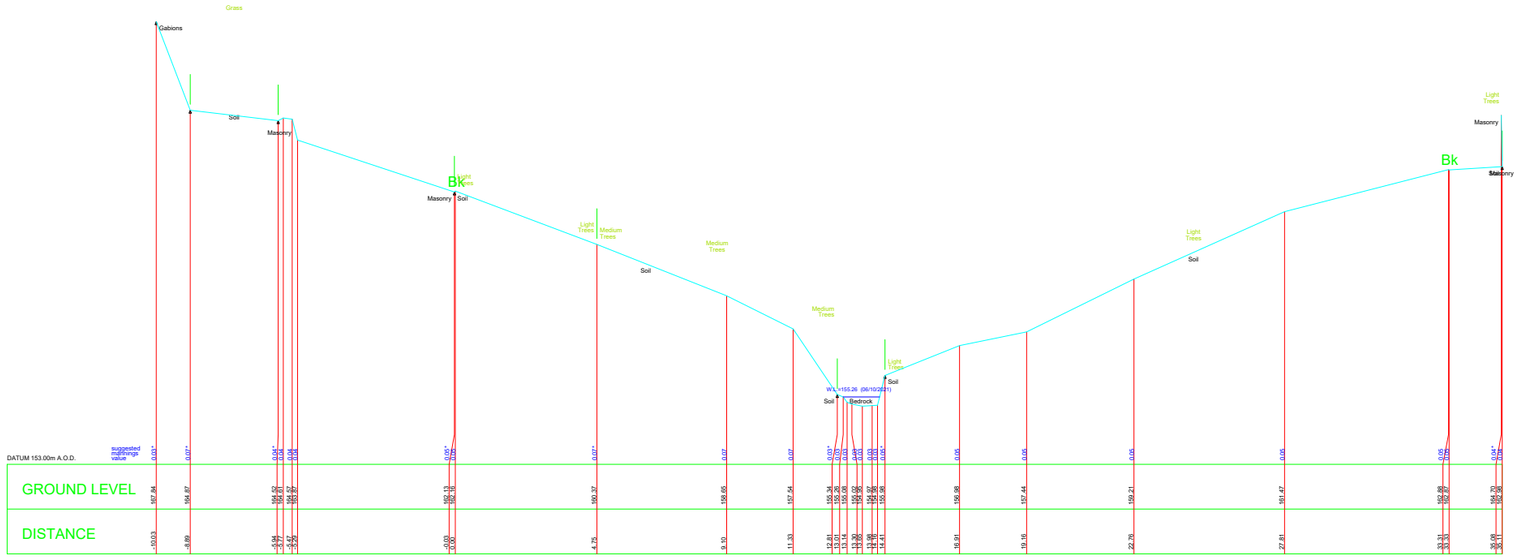
100 0 100 200 300 400 500m
Scale: 1/2500 at A1; 1/5000 at A3

Client	Project		
ENZYGO, THE BYRE TORTWORTH ESTATE, WOODEND LANE, CROMHALL, GL12 8AA	WATERCOURSE SURVEY, BURN ROAD HUDDERSFIELD		
Surveyed: R.F.	Apprd:	R.J.FLEW	DRAWING REFERENCE
Date: 15.10.2021	File Ref:	1784	ISM/BURN ROAD HUDDERSFIELD
Scale: 1/2500 at A1; 1/5000 at A3	Datum	OSTN15/OSGM15	OVERALL PLAN

INFOMAP
SURVEYS AND MAPPING
CHARTERED SURVEYORS
RICS
Seymours House
Sunnyside Road North
Weston-super-Mare
North Somerset BS23 3PZ
Tel: 01934 644060 /fax 01934 644060
E-mail: mail@infomapsurveys.co.uk
Website: www.infomapsurveys.co.uk
ISO 9001 REGISTERED FIRM

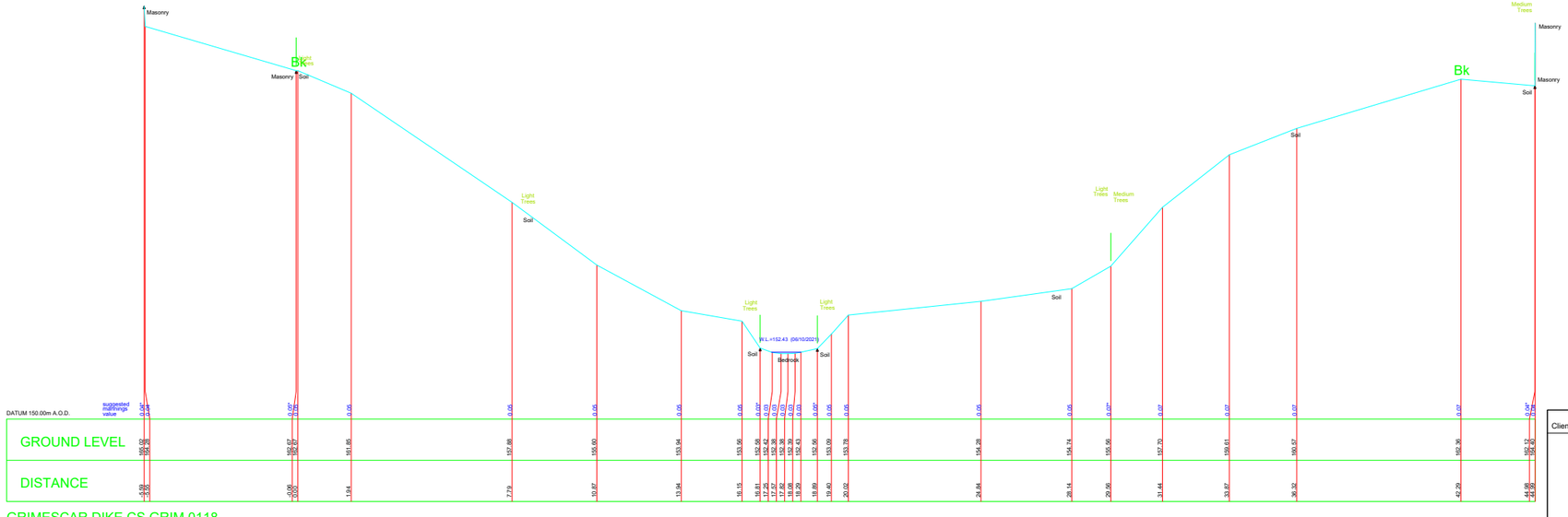

Left Bank
Right Bank
Hallifax Road Bridge
Random Stone Arch Bridge
& 0.725 Dia Concrete Culvert
Structure Length = 109.52 Culvert (81.46m)
3
185.84
184.97
180.38
Culvert
Dia: 725mm
Soffit: 180.38
Invert: 179.66
177.43
Water Level
Hard Bed
Burn Road Bridge
Masonary Arch Road Bridge
Structure Length = 14.21m
Culvert Old Access Track
1.9 Dia Culvert
Structure Length = 10.06m
170.54
1
2
169.32
168.51
168.50
167.77
167.41
165.95
165.68
Culvert
Dia: 1900mm
Soffit: 167.77
Invert: 165.87
Culvert
Dia: 1900mm
Soffit: 167.41
Invert: 165.51
Right Bank
Left Bank
Water Level
Hard Bed
168
167
166
165
164
163
162
161
160
159
158
157
156
155
154
153
152
151
150
149
SCALE: 1/100
DATUM 148.00m A.O.D.

| | | |



GRIMESCAR DIKE CS GRIM.0156

Centre OSNG Coordinates E.412132.32 N.418906.23



GRIMESCAR DIKE CS GRIM.0118

Centre OSNG Coordinates E.412166.42 N.418910.41

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR Light Trees
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

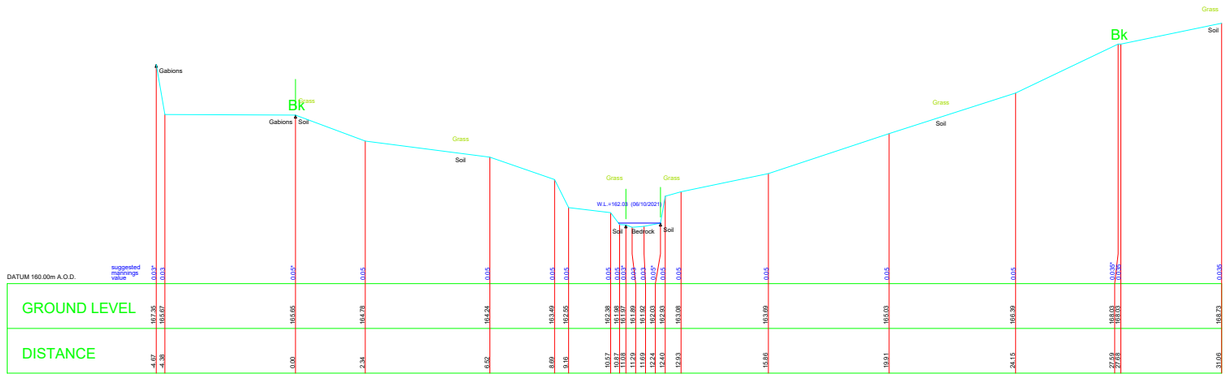
Client	Project	
ENZYGO, THE BYRE, TORTWORTH ESTATE, WOODEND LANE, CROMHALL, GL12 8AA	WATERCOURSE SURVEY BURN ROAD HUDDERSFIELD	
Surveyed: S.M.	Apprd:	R.J.FLEW
Date: 18.10.2021	File Ref:	1784
Scale: 1/2500 at A1; 1/5000 at A3	Datum	OSTN15/OSGM15

INFOMAP
SURVEYS AND MAPPING
CHARTERED SURVEYORS
RICS
Seymours House
Sunnyside Road North
Weston-super-Mare
North Somerset BS23 3PZ
Tel: 01934 644060 /fax 01934 644060
E-mail: mail@infomapsurveys.co.uk
Website: www.infomapsurveys.co.uk
ISO 9001 REGISTERED FIRM

DRAWING REFERENCE

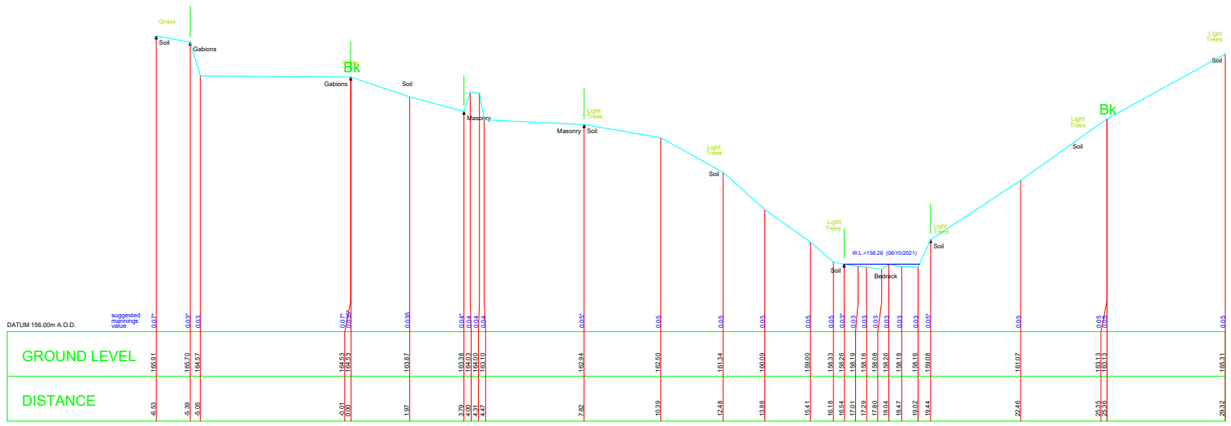
ISM/BURN ROAD HUDDERSFIELD

CROSS SECTIONS-1



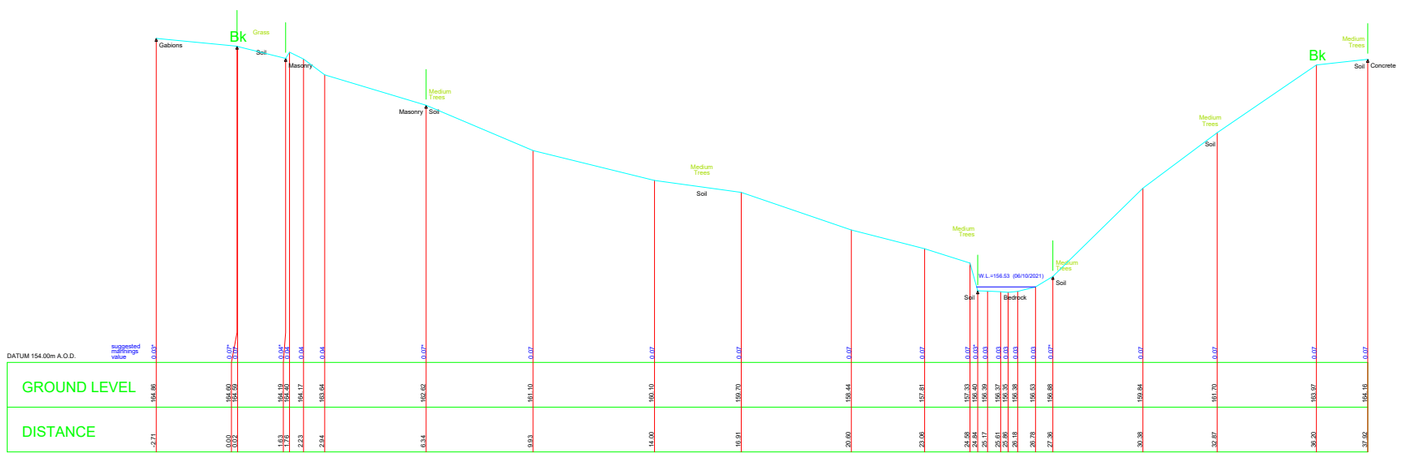
GRIMESCAR DIKE CS GRIM.0251

Centre OSNG Coordinates E.412051.07 N.418902.51



GRIMESCAR DIKE CS GRIM.0206

Centre OSNG Coordinates E.412089.23 N.418894.14



GRIMESCAR DIKE CS GRIM.0172

Centre OSNG Coordinates E.412118.84 N.418896.43

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR Light Trees
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project	
ENZYGO, THE BYRE, TORTWORTH ESTATE, WOODEND LANE, CROMHALL, GL12 8AA	WATERCOURSE SURVEY BURN ROAD HUDDERSFIELD	
Surveyed: S.M.	Apprd:	R.J.FLEW
Date: 18.10.2021	File Ref:	1784
Scale: 1/2500 at A1; 1/5000 at A3	Datum	OSTN15/OSGM15

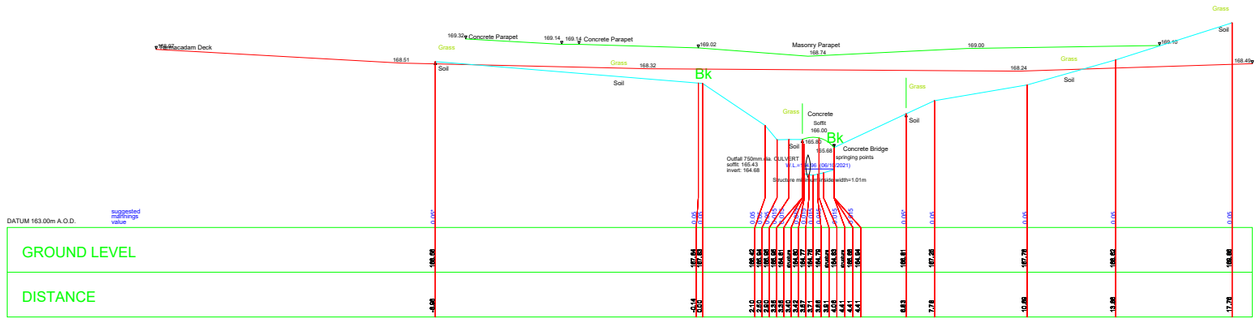
INFOMAP
SURVEYS AND MAPPING
CHARTERED SURVEYORS
RICS
Seymours House
Sunnyside Road North
Weston-super-Mare
North Somerset BS23 3PZ
Tel: 01934 644060 /fax 01934 644060
E-mail: mail@infomapsurveys.co.uk
Website: www.infomapsurveys.co.uk
ISO 9001 REGISTERED FIRM

DRAWING REFERENCE

ISM/BURN ROAD HUDDERSFIELD

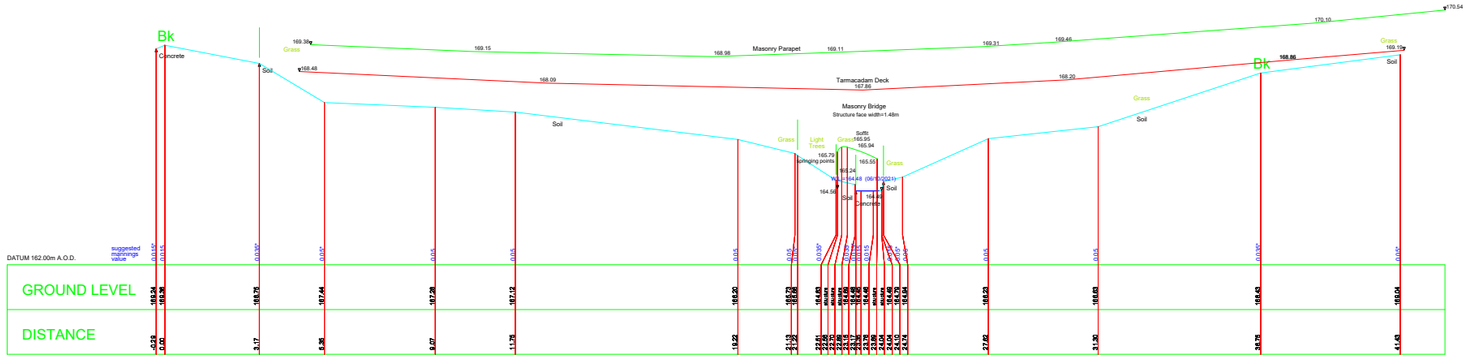
CROSS SECTIONS-2

Structure no. 1. Burn Road Bridge
(upstream face of structure)
Description: Masonary Arch Road Bridge
Structure Length = 14.21m

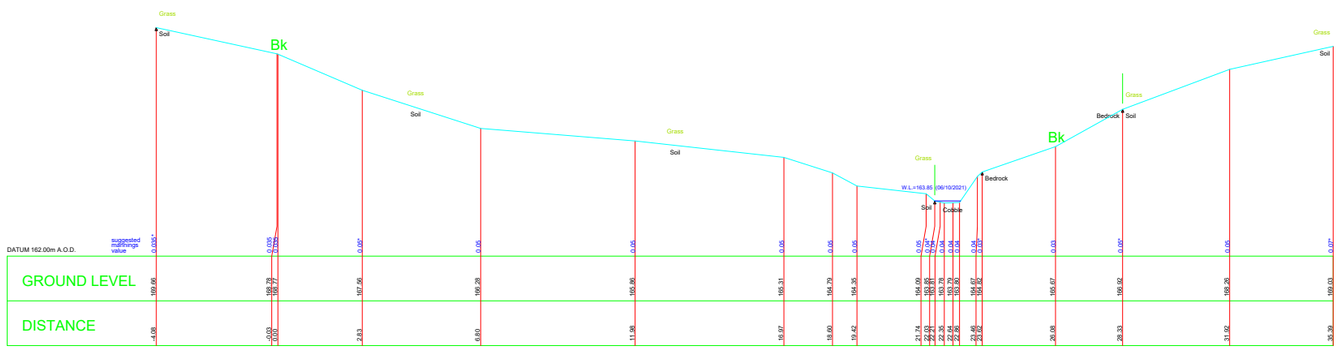


GRIMESCAR DIKE CS GRIM.0303
Centre OSNG Coordinates E.412002.33 N.418896.09

Structure no. 1. Burn Road Bridge
(downstream face of structure)
Description: Masonary Arch Road Bridge
Structure Length = 14.21m



GRIMESCAR DIKE CS GRIM.0289
Centre OSNG Coordinates E.412016.33 N.418894.00



GRIMESCAR DIKE CS GRIM.0277
Centre OSNG Coordinates E.412027.39 N.418895.19

LEGEND FOR SURFACE & VEGETATION CHANGES: Light |
ABOVE GROUND VEGETATION & SEPARATOR Trees |
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

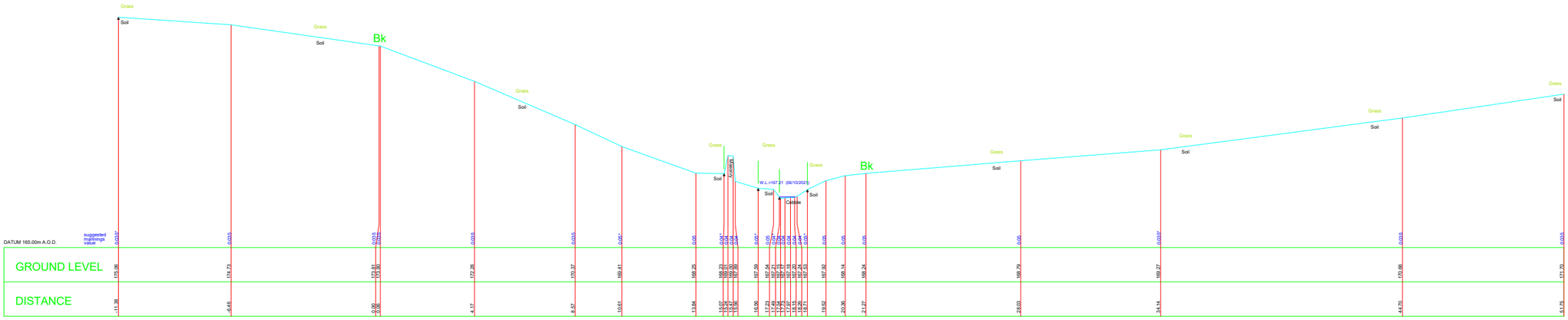
5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project	
ENZYGO, THE BYRE, TORTWORTH ESTATE, WOODEND LANE, CROMHALL, GL12 8AA	WATERCOURSE SURVEY BURN ROAD HUDDERSFIELD	
Surveyed: S.M.	Apprd:	R.J.FLEW
Date: 18.10.2021	File Ref:	1784
Scale: 1/2500 at A1; 1/5000 at A3	Datum	OSTN15/OSGM15

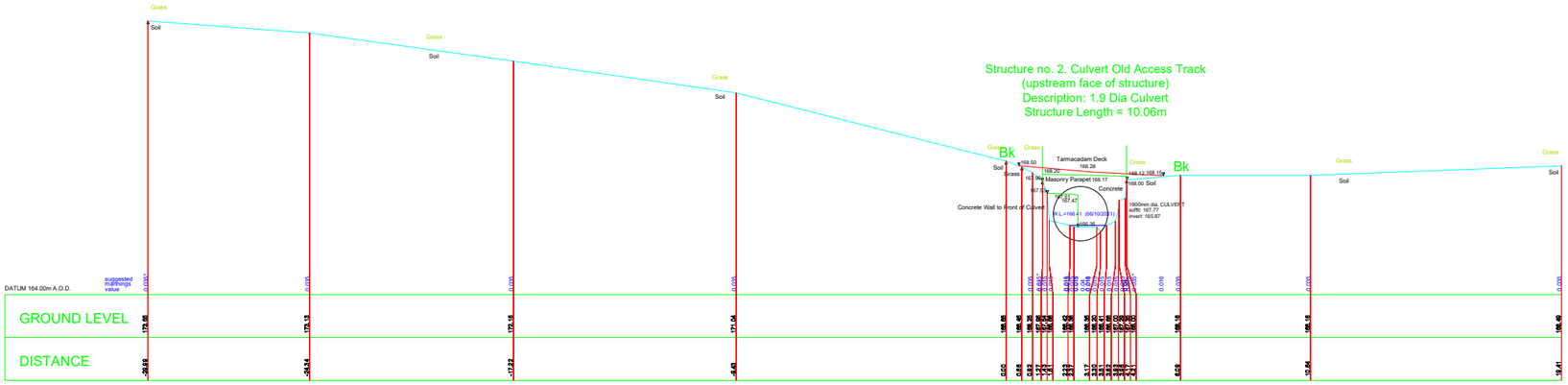
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CROSS SECTIONS-3



GRIMESCAR DIKE CS GRIM.0346

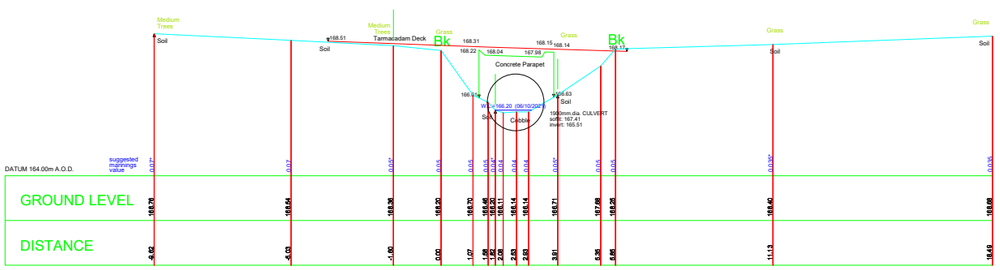
Centre OSNG Coordinates E.411972.45 N.418923.26



GRIMESCAR DIKE CS GRIM.0330

Centre OSNG Coordinates E.411989.90 N.418917.90

Structure no. 2. Culvert Old Access Track
(downstream face of structure)
Description: 1.9 Dia Culvert



GRIMESCAR DIKE CS GRIM.0320

Centre OSNG Coordinates E.411991.24 N.418908.45

LEGEND FOR SURFACE & VEGETATION CHANGES: Light |
ABOVE GROUND VEGETATION & SEPARATOR Trees |
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

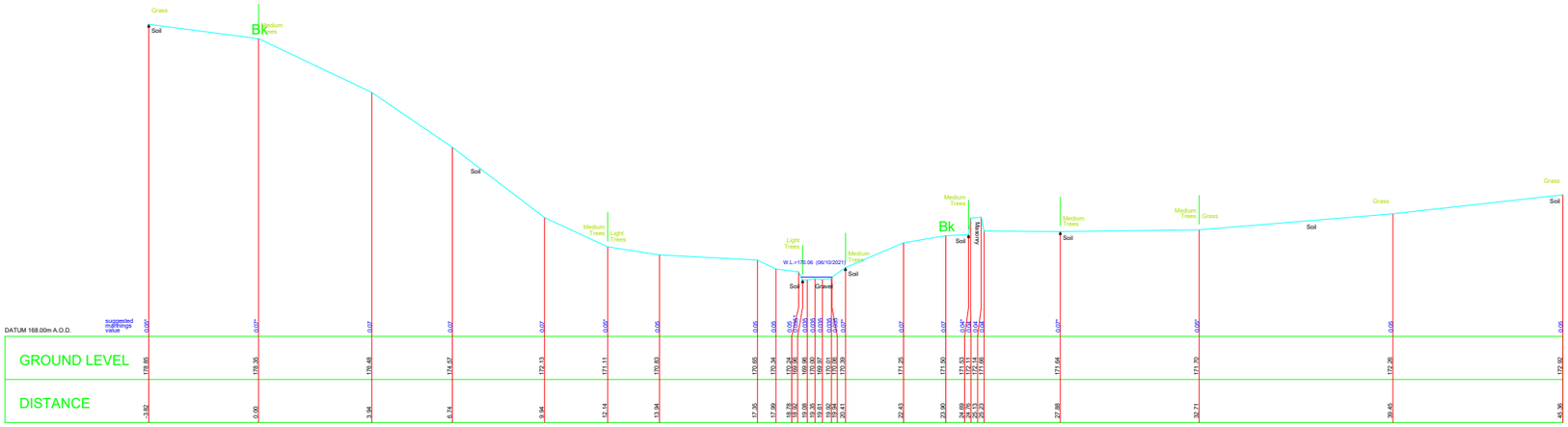
Client	Project		
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Surveyed: S.M.		Apprd:	R.J.FLEW
Date: 18.10.2021		File Ref:	1784
Scale: 1/2500 at A1; 1/5000 at A3		Datum	OSTN15/OSGM15

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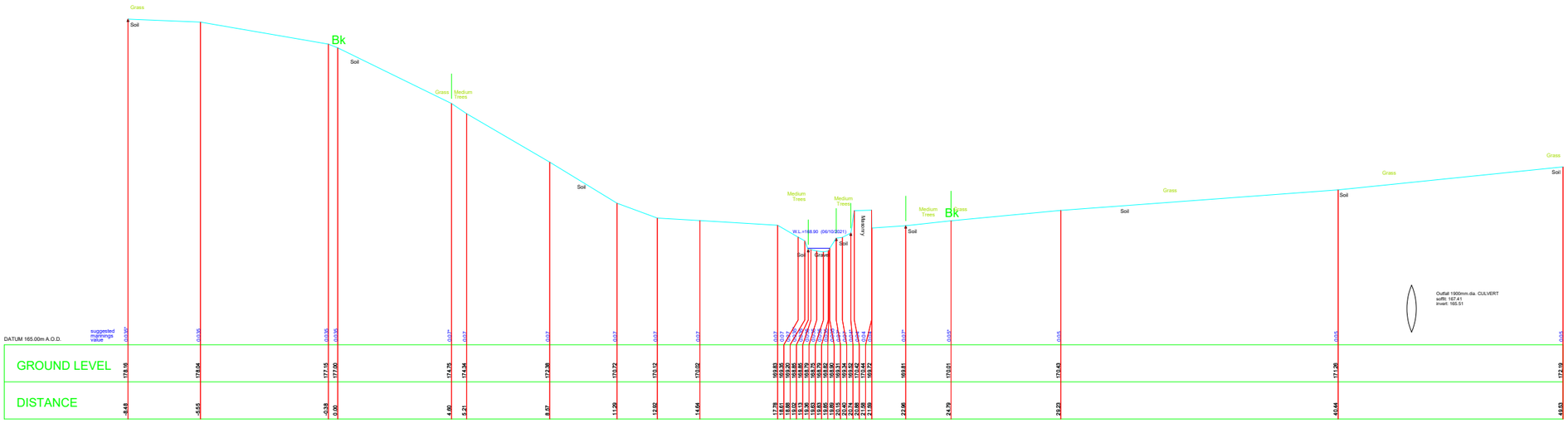
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CROSS SECTIONS-4



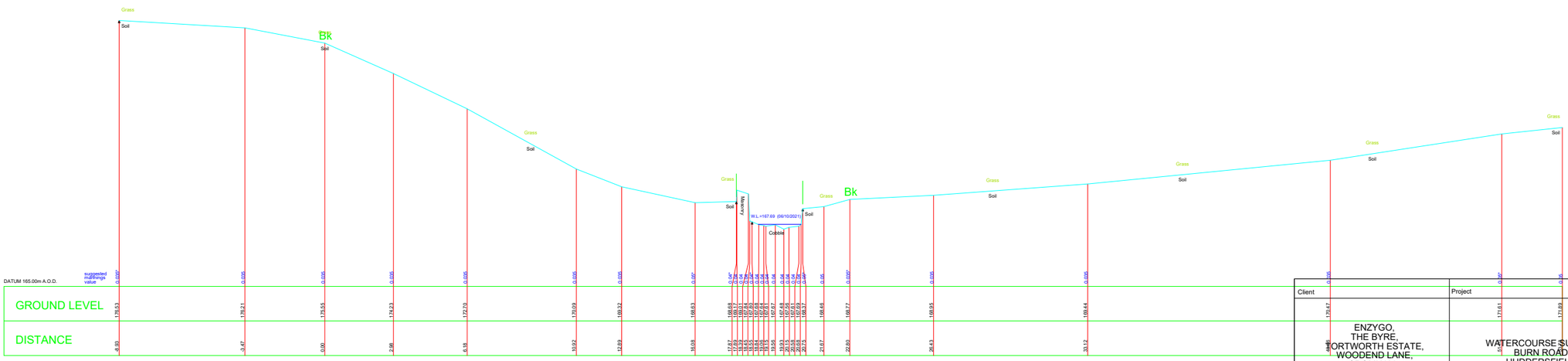
GRIMESCAR DIKE CS GRIM.0413

Centre OSNG Coordinates E.411909.08 N.418936.18



GRIMESCAR DIKE CS GRIM.0384

Centre OSNG Coordinates E.411935.71 N.418927.45



GRIMESCAR DIKE CS GRIM.0359

Centre OSNG Coordinates E.411960.33 N.418925.48

LEGEND FOR SURFACE & VEGETATION CHANGES: Light Trees
ABOVE GROUND VEGETATION & SEPARATOR
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project
ENZYGO, THE BYRE, FORTWORTH ESTATE, WOODEND LANE, CROMHALL, GL12 8AA	WATERCOURSE SURVEY BURN ROAD HUDDERSFIELD

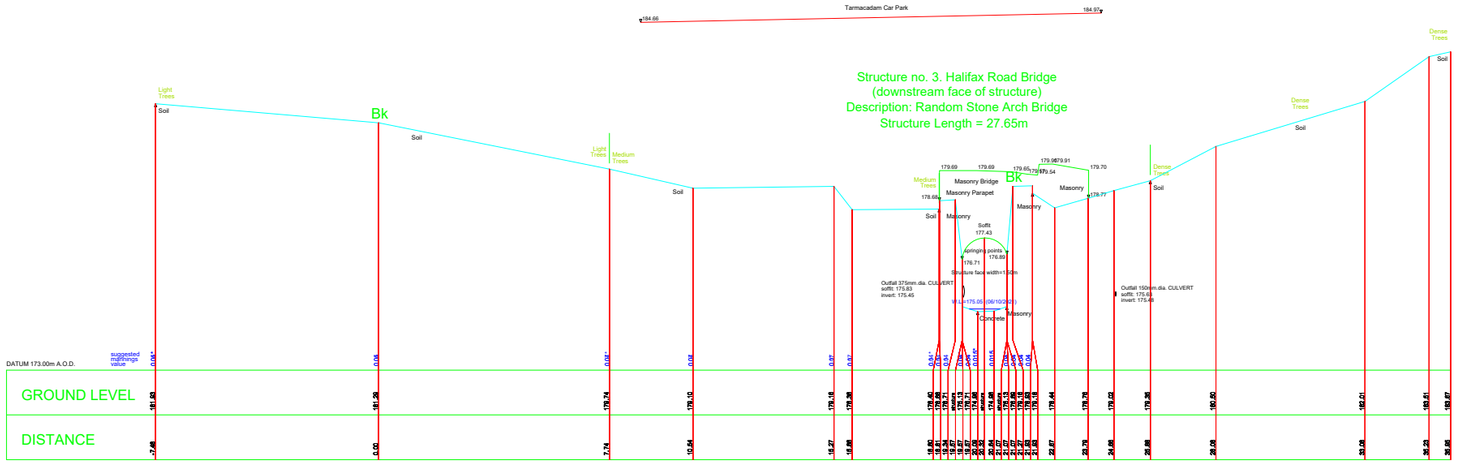
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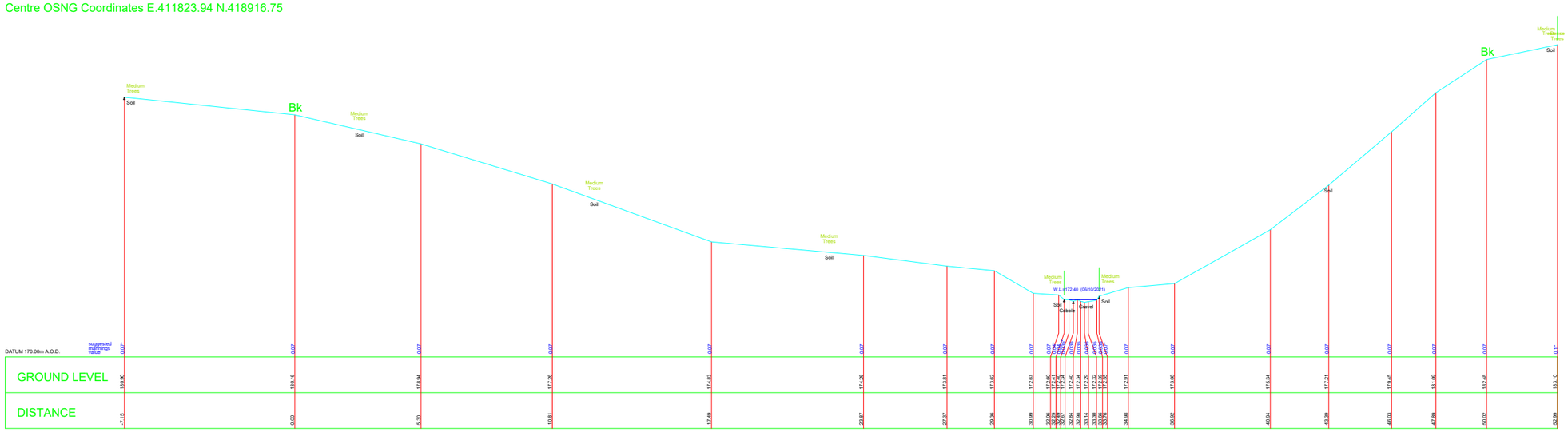
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CROSS SECTIONS-5



GRIMESCAR DIKE CS GRIM.0507

Centre OSNG Coordinates E.411823.94 N.418916.75



GRIMESCAR DIKE CS GRIM.0458

Centre OSNG Coordinates E.411867.99 N.418931.57

LEGEND FOR SURFACE & VEGETATION CHANGES: Light Trees |
ABOVE GROUND VEGETATION & SEPARATOR |
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project
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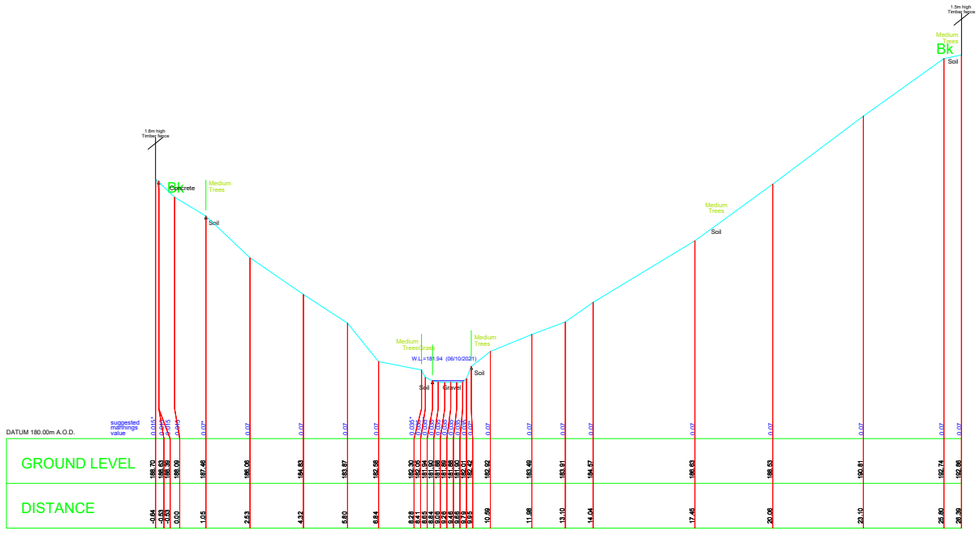
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Scale: 1/2500 at A1; 1/5000 at A3	Datum	OSTN15/OSGM15

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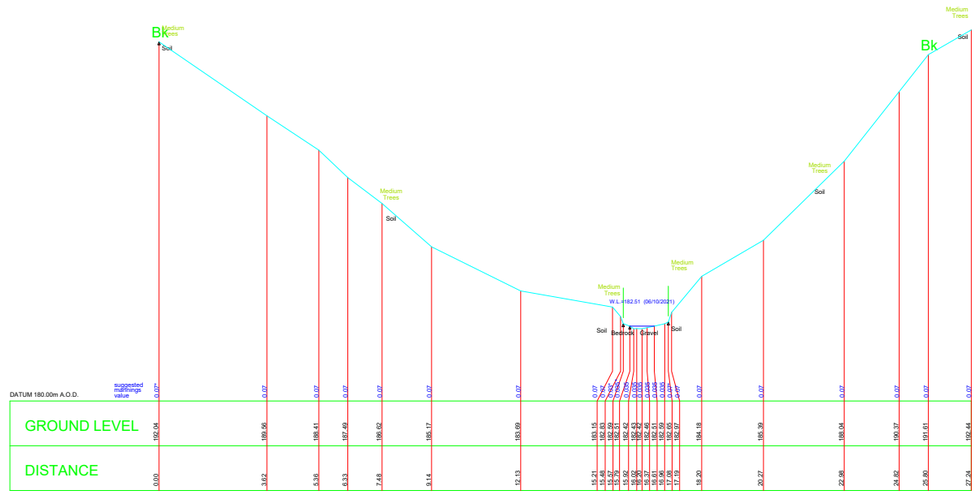
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CROSS SECTIONS-6



GRIMESCAR DIKE CS GRIM.0661

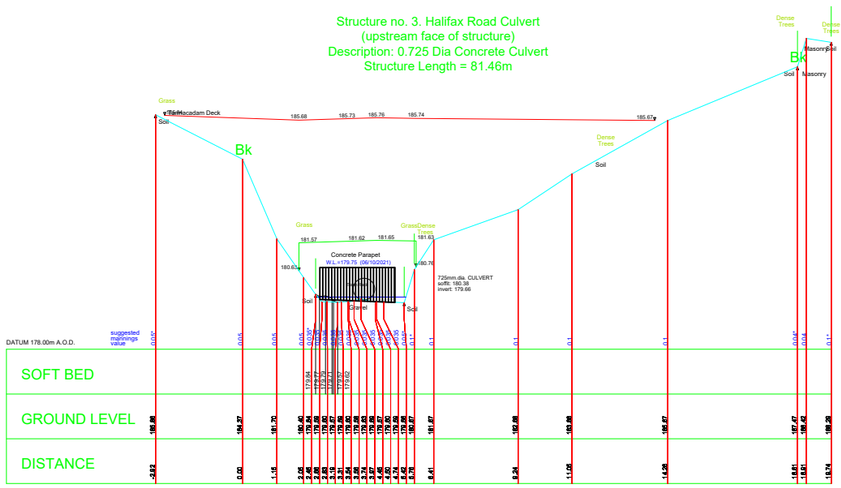
Centre OSNG Coordinates E.411680.62 N.418865.88



GRIMESCAR DIKE CS GRIM.0678

Centre OSNG Coordinates E.411665.77 N.418858.54

Structure no. 3. Halifax Road Culvert
(upstream face of structure)
Description: 0.725 Dia Concrete Culvert
Structure Length = 81.46m



GRIMESCAR DIKE CS GRIM.0616

Centre OSNG Coordinates E.411719.53 N.418883.82

LEGEND FOR SURFACE & VEGETATION CHANGES: Light |
ABOVE GROUND VEGETATION & SEPARATOR Trees |
GROUND SURFACE & SEPARATOR stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

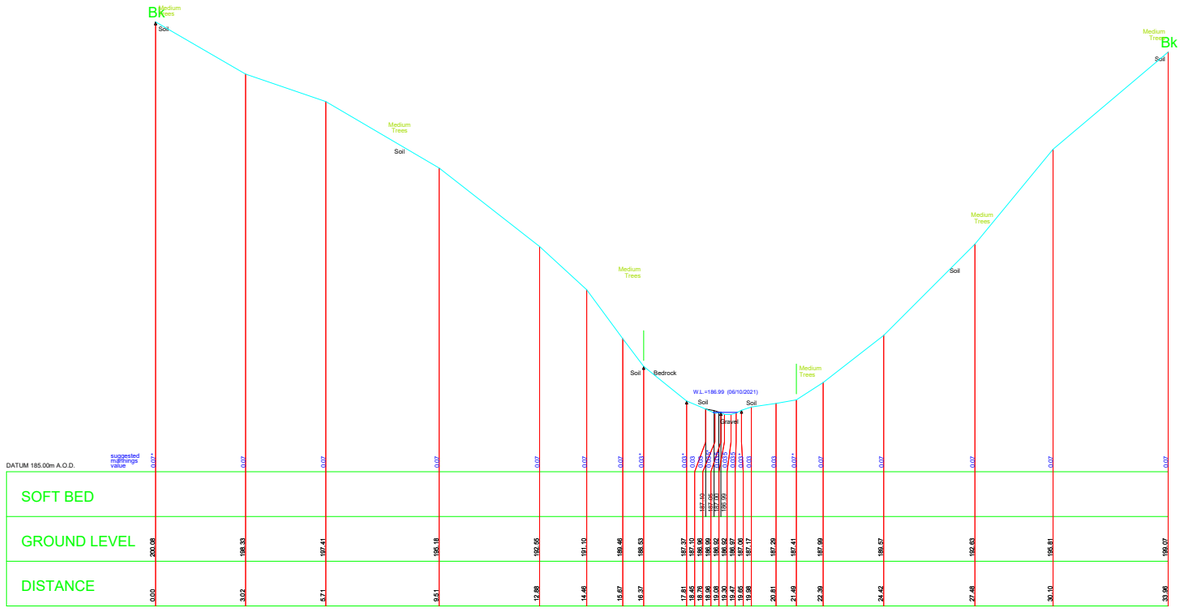
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Surveyed: S.M.	Apprd:	R.J.FLEW
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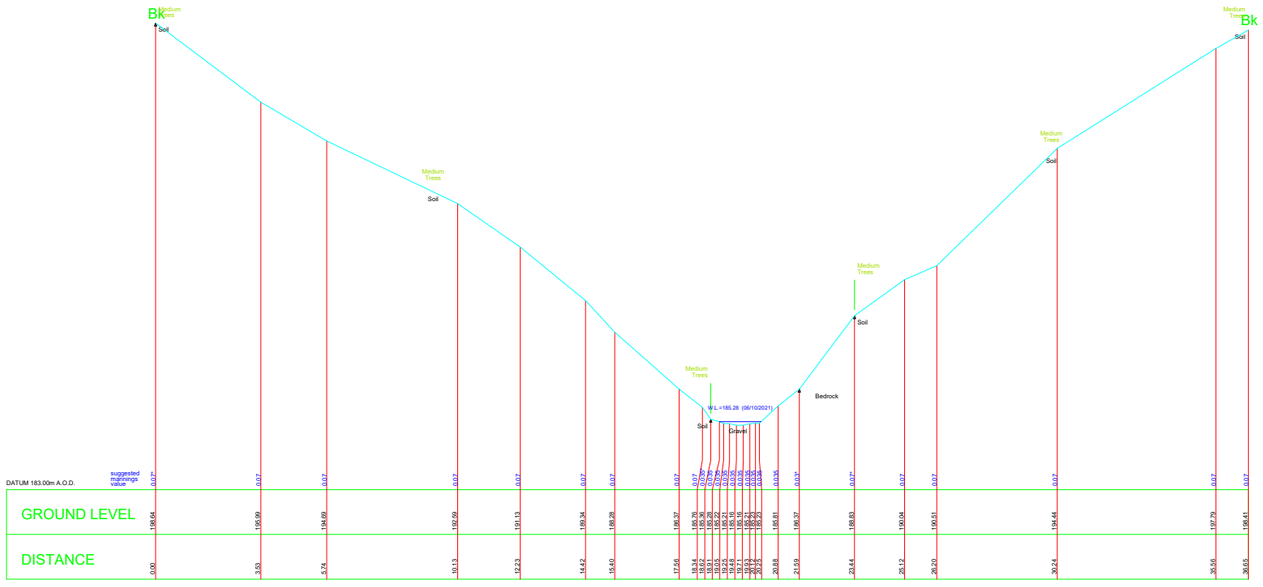
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CROSS SECTIONS-7



GRIMESCAR DIKE CS GRIM.0771

Centre OSNG Coordinates E.411576.56 N.418840.18



GRIMESCAR DIKE CS GRIM.0736

Centre OSNG Coordinates E.411610.60 N.418847.94

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR: Light Trees I
GROUND SURFACE & SEPARATOR: stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project
ENZYGO, THE BYRE, TORTWORTH ESTATE, WOODEND LANE, CROMHALL, GL12 8AA	WATERCOURSE SURVEY BURN ROAD HUDDERSFIELD

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Appendix 4 – Tabulated 1D Model Results

Model Node	Burn Road - Watercourse 1 in Channel Flood Levels Sensitivity and Blockage Runs (Elevation in mAOD)							Burn Road - Watercourse 1 in Channel Flood Levels Difference compared to Baseline (m)					
	Baseline (001)	002a	002b	003a	004a	004b	005	002a	002b	003a	004a	004b	005
	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year	1 in 100-year
GRIM_0771.1	187.29	187.29	187.29	187.29	187.32	187.25	187.28	0.00	0.00	0.00	0.03	-0.03	-0.01
GRIM_0736.1	185.53	185.53	185.53	185.53	185.57	185.50	185.53	0.00	0.00	0.00	0.03	-0.04	-0.01
Culvert 1.1	182.90	184.01	182.90	182.90	182.94	182.85	181.18	1.11	0.00	0.00	0.04	-0.05	-1.72
GRIM_0678.1	182.20	184.00	182.20	182.20	182.23	182.16	182.87	1.81	0.00	0.00	0.03	-0.04	0.67
GRIM_0661A.1	181.13	184.00	181.13	181.13	181.13	181.13	181.14	2.88	0.00	0.00	0.00	0.00	0.02
Culvert 1.2	178.18	177.63	178.18	178.18	178.18	178.18	178.18	-0.55	0.00	0.00	0.00	0.00	0.00
Culvert 2.2	175.37	175.34	175.37	175.37	175.40	175.32	175.55	-0.03	0.00	0.00	0.04	-0.04	0.19
GRIM_0458.1	172.70	172.67	172.70	172.70	172.73	172.65	172.83	-0.03	0.00	0.00	0.04	-0.04	0.14
GRIM_0458.2	170.47	170.43	170.47	170.47	170.52	170.42	170.62	-0.04	0.00	0.00	0.05	-0.05	0.15
GRIM_0413.1	169.22	169.20	169.22	169.22	169.27	169.18	169.40	-0.03	0.00	0.00	0.04	-0.04	0.18
GRIM_0384.1	167.94	167.91	167.94	167.94	167.98	167.90	168.10	-0.03	0.00	0.00	0.04	-0.04	0.16
GRIM_0359.1	167.62	167.64	167.62	167.62	167.66	167.58	167.73	0.01	0.00	0.00	0.04	-0.04	0.10
Culvert 3.1	166.65	166.59	166.65	166.65	166.65	166.65	166.98	-0.06	0.00	0.00	0.00	0.00	0.33
Culvert 3.2	166.46	166.44	166.46	166.46	166.50	166.43	166.60	-0.02	0.00	0.00	0.03	-0.04	0.14
Culvert 4.1	165.70	165.62	166.21	165.70	165.70	165.70	166.19	-0.08	0.51	0.00	0.00	0.00	0.50
Culvert 4.2	164.89	164.86	164.89	164.89	164.93	164.84	165.07	-0.03	0.00	0.00	0.04	-0.05	0.18
GRIM_0289.1	164.23	164.19	164.23	164.23	164.27	164.18	164.42	-0.03	0.00	0.00	0.05	-0.05	0.19
GRIM_0277.1	162.22	162.20	162.22	162.22	162.25	162.19	162.34	-0.02	0.00	0.00	0.03	-0.03	0.12
GRIM_0251.1	158.44	158.42	158.44	158.44	158.47	158.41	158.57	-0.02	0.00	0.00	0.03	-0.03	0.13
GRIM_0206.1	156.69	156.67	156.69	156.69	156.72	156.65	156.83	-0.02	0.00	0.00	0.03	-0.04	0.14
GRIM-0172.1	155.28	155.26	155.28	155.28	155.31	155.24	155.42	-0.02	0.00	0.00	0.03	-0.04	0.14
GRIM-0172.2	152.91	152.88	152.91	152.91	152.91	152.91	153.16	-0.04	0.00	0.00	0.00	0.00	0.24
Model_Out.2	152.38	152.38	152.38	152.38	152.38	152.38	152.38	0.00	0.00	0.00	0.00	0.00	0.00
Average Change								0.21	0.02	0.00	0.03	-0.03	0.09



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